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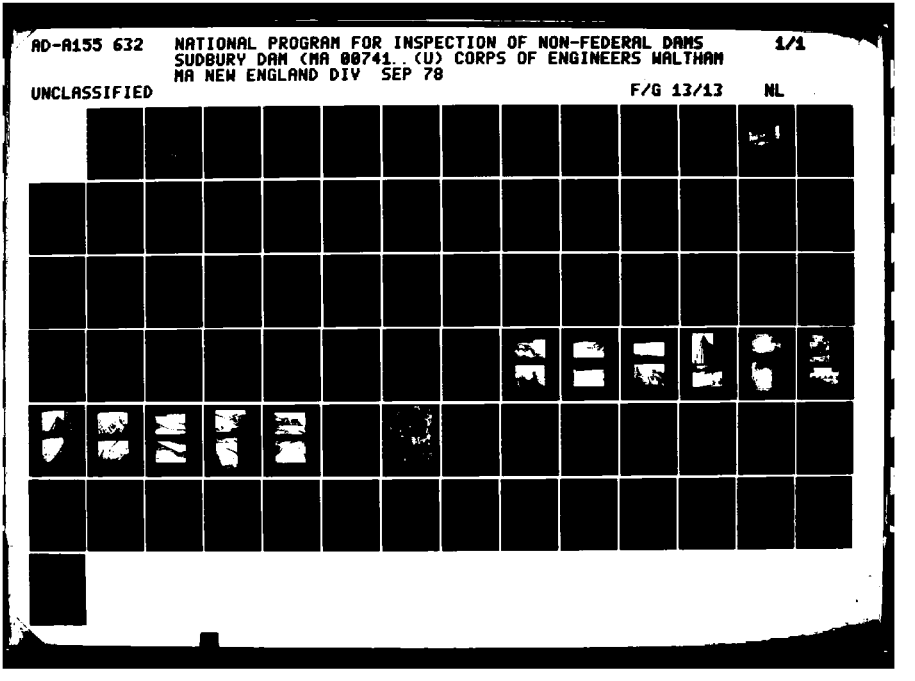

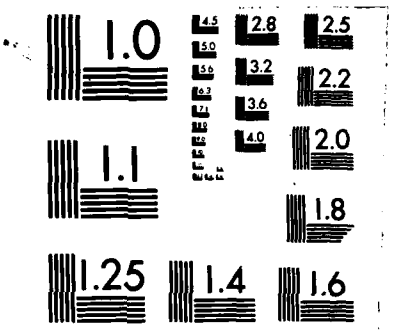

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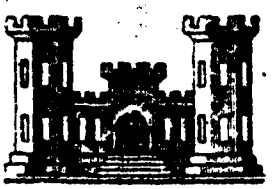
MERRIMACK RIVER BASIN
SOUTHBOROUGH, MASSACHUSETTS

SUDBURY DAM

MA 00741

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

SEPTEMBER 1978

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Merrimack river Basin
Southborough, Massahcusetts
Stony Brook

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The dam is that of intemediate size, consisting of an earht embankment about 70 ft. high and a central stone masonry ogee spillway, together about 2000 ft. long. It classified as high in the hazard potential category. The dam is generally in good condition. The MDC should perform additional investigations to determine the stability of the spillway weir. Recommendations for remedial work include cutting of grass and brush on the downstream slope.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED

Honorable Michael S. Dukakis
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts 02133

NOV 29 1978

Dear Governor Dukakis:

I am forwarding to you a copy of the Sudbury Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. In addition, a copy of the report has also been furnished the owner, the Metropolitan District Commission, Commonwealth of Massachusetts, 80 Somerset Street, Boston, Massachusetts 02108, ATTN: Mr. Martin Weis, Chief Engineer.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

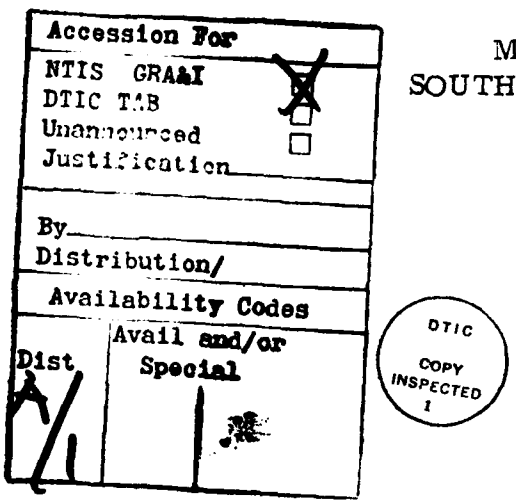
I wish to take this opportunity to thank you and the Department of Environmental Quality Engineering for your cooperation in carrying out this program.

Sincerely yours,

JOHN P. CHANDLER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

SUDBURY DAM
MA 00741



MERRIMACK RIVER BASIN
SOUTHBOROUGH, MASSACHUSETTS

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

BRIEF ASSESSMENT

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM

Identification No.:	MA 00741
Name of Dam:	Sudbury Dam
Town:	Southborough
County:	Worcester
State:	Massachusetts
Stream:	Stony Brook
Date of Site Visit:	30 June 1978

Sudbury Dam is a dam of intermediate size, consisting of an earth embankment approximately 70 ft. high and a central stone masonry ogee spillway, together approximately 2000 ft. long. The dam, constructed for water supply in 1896, is classified in the "high" hazard potential category.

The dam is generally in good condition. There were no obvious signs of failure or conditions which would warrant urgent remedial treatment.

Hydraulic analyses indicate that the spillway is adequate in size to safely pass the test flood, determined to be the probable maximum flood, without overtopping the dam.

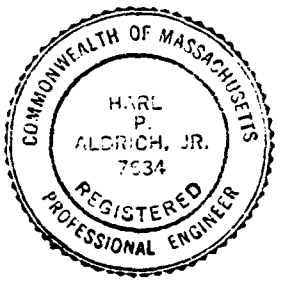
The MDC should perform additional investigations to determine the stability of the spillway weir, especially the top ten feet at the crest, under loading from the test flood and from seismic forces. An investigation to evaluate seepage and embankment slope stability left of the spillway should also be undertaken.

Recommendations for remedial work include cutting of grass and brush on the downstream slope and immediately downstream of the toe, and pointing of facing stones at the spillway crest and elsewhere as required.

The recommendations and remedial measures described in Section VII should be implemented by the owner within 24 months after receipt of this Phase I Inspection Report.

HALEY & ALDRICH, INC.
by:

Harl Aldrich
President



This Phase I Inspection Report on Sudbury Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Charles G. Tiersch

CHARLES G. TIERSCH, Chairman
Chief, Foundation and Materials Branch
Engineering Division

Fred J. Ravens Jr

FRED J. RAVENS, Jr., Member
Chief, Design Branch
Engineering Division

Saul Cooper

SAUL COOPER, Member
Chief, Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D. C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testting, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I investigations are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the test flood is based on the estimated "probable maximum flood" for the region (greatest resonably possible storm runoff), or a fraction thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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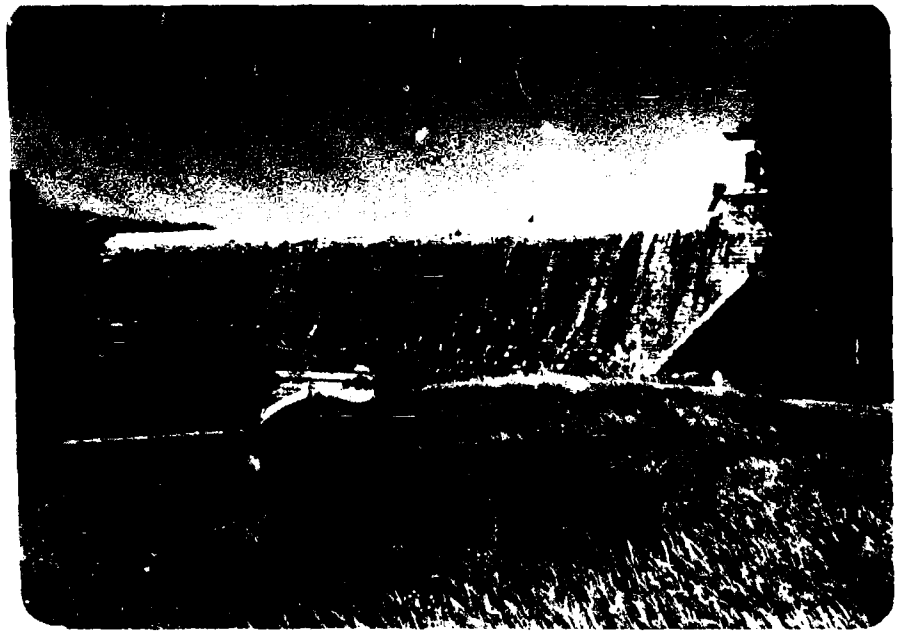
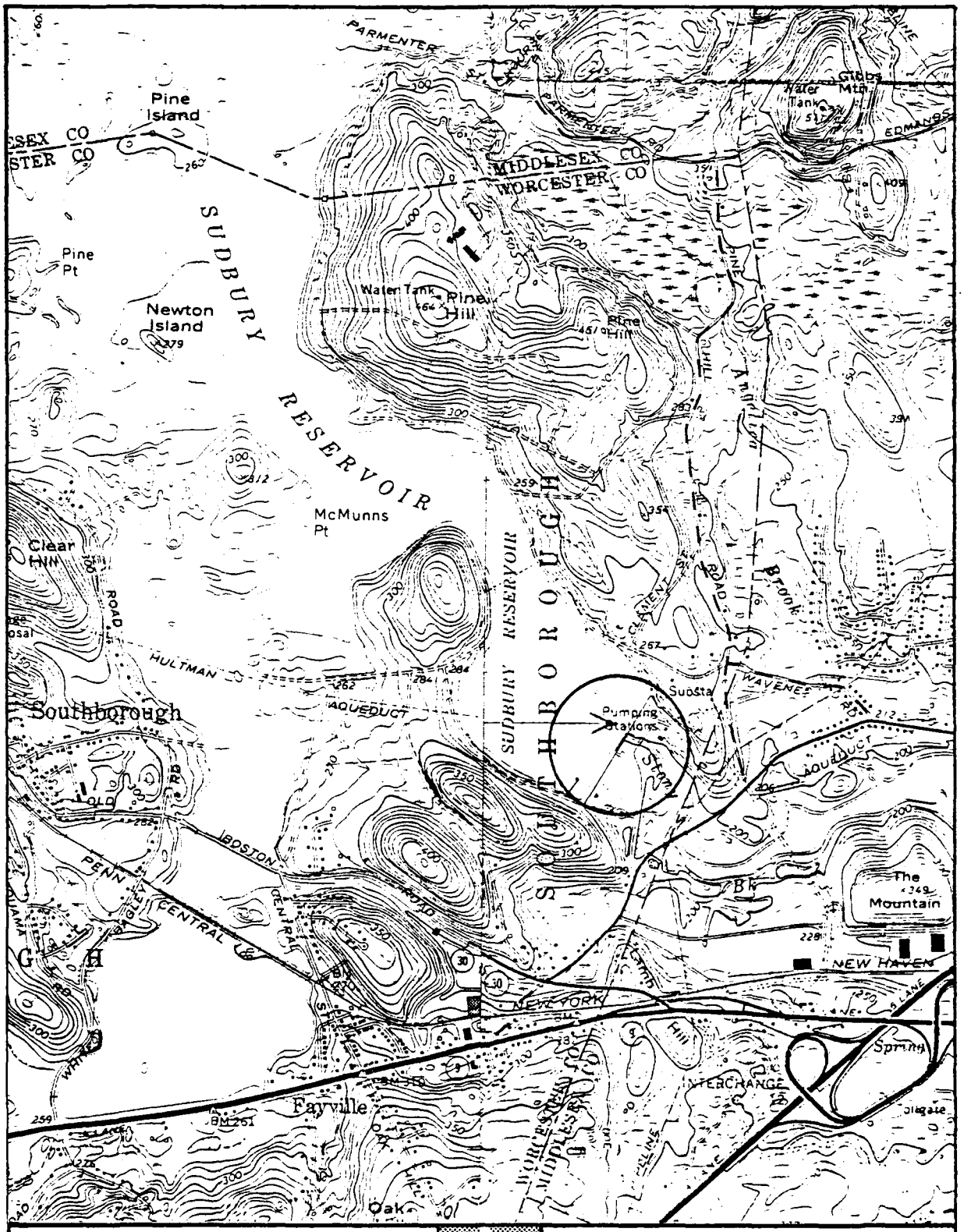


Overview Photo of Sudbury Dam (Roll C11, Frame 19A)



FILE NO. 4160 A15

DAM: Sudbury Dam

IDENTIFICATION NO. MA 00741

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LOCATION MAP
USGS QUADRANGLE
FRAMINGHAM, MA.
APPROX. SCALE: 1"= 2000'

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM
SUDBURY DAM
IDENTIFICATION NO. MA 00741

I. PROJECT INFORMATION

1.1 GENERAL

A. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region.

Haley & Aldrich, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed were issued to Haley & Aldrich, Inc. under a letter dated 26 April 1978 from Colonel Ralph T. Garver, Corps of Engineers. Contract No. DACW33-78-C-0301 has been assigned by the Corps of Engineers for this work. Camp, Dresser & McKee, Inc. was retained as consultant to Haley & Aldrich, Inc. on the structural, mechanical/electrical and hydraulic/hyrologic aspects of the investigation

B. Purpose. The primary purposes of the National Dam Inspection Program are to:

1. Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

2. Encourage and prepare the states to initiate quickly effective dam safety programs for non-Federal dams.

3. To update, verify and complete the National Inventory of Dams.

1.2 PROJECT DESCRIPTION

A. Location. The dam is located in the town of Southborough, MA approximately one-half mile north of Route 9 and just west of the boundary between Worcester and Middlesex Counties, as shown on the Location Map, page vi. Overflow from the dam is carried by Stony Brook to MDC Framingham Reservoir No. 3.

B. Dam and Appurtenances. Sudbury Dam consists of an earth embankment, an ungated granite-faced spillway near the middle of the embankment, and a gate house structure. The total length of the dam is about 2000 ft. Plans, profiles and sections are shown on drawings in Appendix B.

The right and left embankments are approximately 45 ft. and 70 ft. high, respectively. Slopes are 2 horizontal to 1 vertical on the upstream side and the upper part of the downstream side. The lower part of the downstream slope is 2.5 to 1. The embankments consist of a concrete core wall bearing on rock and earth fills as shown by Appendix B-4. The upstream face is protected by riprap and stone paving. There is a gravel service road at the crest and the downstream slope is covered by grass, weeds and brush.

The spillway is an ogee type founded on rock. It is 300 ft. long, with a maximum height of approximately 71.5 ft. A cross-section of the spillway is shown in Appendix B-2.

A gate house structure is located at the left end of the spillway. The structure consists of three intake chambers each connected to 48-in. diameter outlet conduits. Details of the gate house are shown in Appendix B-2, 3 and 5. Note that only one of the 48-in. conduits presently discharges at the toe of the spillway upstream of the access road bridge.

C. Size Classification. Sudbury Dam has an estimated storage to the top of the dam of 33,020 acre-feet, and a maximum height of about 70 ft. Storage between 1,000 and 50,000 acre-feet and a height of from 40 to 100 ft. classifies Sudbury Dam in the "intermediate" size category, according to guidelines established by the Corps of Engineers.

D. Hazard Classification. Sudbury Dam is currently classified as having a "high" hazard potential in the Corps of Engineers National

Inventory of Dams. A dam failure analysis, Appendix D, indicates the potential for loss of lives and extensive damage to homes, buildings, bridges and roadways downstream. Therefore, it is recommended that this classification be retained.

E. Ownership. The dam is owned by the Massachusetts Metropolitan District Commission, 20 Somerset Street, Boston, MA 02108.

F. Operator. The operation of the dam is the responsibility of the Sudbury Section of the MDC, 311 Hollis St., Framingham, MA. The Superintendent of the Sudbury Section is Mr. Edward Ginsburg (phone: (617) 872-4388). The plant engineer at the site is Mr. Joseph P. Young (phone: (617) 872-3793).

G. Purpose of the Dam. The dam was constructed to create a water supply reservoir for the Boston Metroplitan area. In about 1915, the gate house was modified for power generation, believed to be two 275 K.V.A. generators and one 900 K.V.A. generator. The facility is now used for water supply only.

H. Design and Construction History. Sudbury Dam was completed in 1896. Five record drawings dated 1899 are included in Appendix B. Some repairs were made on the spillway in 1956 and the outlet conduits from the gatehouse were re-routed at some unknown time. The circular outlet downstream of the spillway no longer exists in the form shown on the record drawings. However, no major structural changes to the embankment and spillway have been made since the dam was constructed.

I. Normal Operational Procedures. The water impounded by the dam is used as part of a water supply by the Metropolitan District Commission of Massachusetts. The spillway flashboards normally remain in place. Water is not taken directly into the transmission system from the dam, but is released into the downstream channel which flows to Framingham Reservoir #3. Water is usually taken from this complex only in periods of high demand.

1.3 PERTINENT DATA

All record plans for the Sudbury Dam are on Boston City Datum. However, elevations reported hereinafter are on the National Geodetic Vertical Datum (NGVD). To convert to NGVD, subtract 5.65 ft. from elevations which are on the Boston City Datum.

A. Drainage Area. The Sudbury River drains a total area of about 163 square miles and originates at Cedar Swamp Pond in Westborough, MA. The drainage area upstream of Sudbury Dam is approximately 22.3 square miles of flat to rolling terrain.

B. Discharge at Dam Site.

1. Outlet Works	3 48-in. pipes (see Section 1.3J for details)
2. Maximum known impoundment at dam site	El. 256.12 on 19 August 1955 (according to the MDC)
3. Ungated spillway capacity at top of dam (with flashboards removed)	23,200 cfs at El. 260.35
4. Ungated spillway capacity at test flood pool elevation	
(with flashboards)	11,100 cfs at El. 259.5
(without flashboards)	11,100 cfs at El. 257.8
5. Gated spillway capacity at normal pool elevation	N/A
6. Gated spillway capacity at test flood pool elevation	N/A
7. Total spillway capacity at test flood pool elevation (with flashboards)	11,100 cfs at El. 259.5
8. Total project discharge at test flood pool elevation (with flashboards)	11,100 cfs at El. 259.5

C. Elevation (ft. above MSL, NGVD Datum)

1. Top dam	260.35
2. Test flood pool-design surcharge	
(with flashboards)	258.6
(without flashboards)	257.1
3. Design surcharge - original design	Unknown
4. Full flood control pool	259.35 assuming 1 ft. freeboard
5. Water supply pool	253.35

6. Spillway crest	
(with flashboards).....	254.52
(without flashboards).....	253.35
7. Upstream portal invert diversion tunnel	
Upper Level.....	236.85
Middle Level.....	217.35
Lower Level.....	196.44
8. Streambed at centerline of dam.....	196.4
9. Maximum tailwater.....	Unknown

D. Reservoir

1. Length of maximum pool (at PMF)...	22,500 ft. (Est.)
2. Length of water supply pool (Normal).	22,500 ft. (Est.)
3. Length of flood control pool.....	N/A

E. Storage (acre-feet)

1. Top of dam.....	33,020 (Est.)
2. Test flood pool.....	27,980 (Est.)
3. Flood control pool.....	N/A
4. Water supply pool.....	22,260 (Est.)
5. Spillway crest.....	22,260 (Est.)

F. Reservoir Surface (acres)

1. Top of dam.....	1780 (Est.)
2. Test flood pool (at PMF).....	1570 (Est.)
3. Flood-control pool.....	N/A
4. Water supply pool.....	1280 (Est.)
5. Spillway crest.....	1280 (Est.)

G. Dam Embankment

1. Type.....	Earth embankment
2. Length.....	Approx. 2000 ft., less spillway
3. Height.....	Approx. 70 feet
4. Top Width.....	Approx. 12 feet
5. Side Slopes.....	2:1 U/S, 2:1 and 2.5 D/S

6. Zoning	"Boulder Clay Puddle" U/S; "Sand and Gravel" D/S
7. Impervious core	Concrete Core Wall
8. Cutoff	Concrete Core Wall
9. Grout curtain	None

H. Diversion and Regulating Facilities. Not applicable.

I. Spillway

1. Type	Ungated masonry ogee weir (granite faced)
2. Length of weir	300 ft.
3. Crest elevation	253.35
4. Flashboards	14 in. high
5. U/S Channel	50-ft. depth behind spillway
6. D/S Channel	Shaped discharge channel
7. General	Excellent hydraulic condition

J. Regulating Outlets. The intake inverts at the outlet structure are elevation 191.35, 217.35 and 236.85. There are presently four 48-in. pipes from the reservoir. One of the pipes is capped and is unuseable. One of the pipes outlets immediately downstream of the spillway at approximately El. 185. The two remaining pipes flow through increasers, 60-in. pipes, an underground vault, and additional piping to discharge through a rectangular outlet in the invert of the channel downstream of the access roadway bridge. The pipe lines are controlled by sluice gates and valves in the outlet structure. The pipe lines to the rectangular outlet have additional valve control away from the main body of the dam. These outlets could be used to lower the reservoir level although no estimates are available of their discharge capacity.

II. ENGINEERING DATA

2.1 DESIGN RECORDS

Five record drawings dated 1899, prints of which are included in Appendix B, indicate the general configuration of the dam when it was constructed. With the exception of a drawing showing details of the spillway channel and stone masonry wall, no detailed design drawings, calculations or other records for the original project were located.

In about 1915, the control house was modified to accommodate power generation equipment. Several drawings are available to show this "Proposed Hydro-Electric Plant". No other modifications to the original design are believed to have occurred.

A list of available documents is included in Appendix B.

2.2 CONSTRUCTION RECORDS

Record drawings for the original construction in the 1890's, are included in Appendix B.

The only other construction records for the dam located involved the repointing of the spillway in 1956 and removal of the power generating equipment in 1970. See Appendix B-7 for a list including the contracts for this work.

2.3 OPERATION RECORDS

Monthly reservoir water surface elevations and daily water supply records were the only operational records located during the investigation.

2.4 EVALUATION

A. Availability. Available design, construction and operation records are located at Sudbury Dam in Southborough, MA and at the MDC, 20 Somerset Street, Boston, MA 02108.

B. Adequacy. The 1899 Record Drawings appear to provide sufficiently accurate data which in combination with the visual examination described in the following section, are adequate for the purposes of the Phase I Investigation.

C. Validity. There is no reason to doubt the validity of the available data.

III. VISUAL EXAMINATION

3.1 FINDINGS

A. General. The Phase I visual examination of Sudbury Dam was conducted on 30 June 1978.

In general, the dam embankment and spillway were found to be in good condition. Some minor deficiencies which require correction were noted.

A visual inspection check list is included in Appendix A and selected photographs of the project are given in Appendix C.

B. Dam. The earth embankment located right and left of the spillway is generally in good condition. There was no evidence of settlement, lateral movement or other serious defects. The upstream slope is paved with large cut stones and is in excellent condition, Photo No. 6.

The following specific items were noted:

1. Wet areas at the downstream toe were noted at two locations. At the toe of the embankment immediately adjacent to the downstream end of the right spillway training wall, there is a wet area approximately 30 to 40 ft. long and 20 ft. wide. There was no active flow. A large wet area occurs at the toe of the embankment left of the spillway. The location is shown in Photos No. 3, 4 and 17. Cattails cover most of the area which extends a few feet up the embankment slope. The presence of blackberry bushes on the slope above the cattails suggests a moist area, Photo No. 4. Again, no active flow was noted.

2. The embankment slopes are generally covered by knee-high grass, weeds and brush. In addition to the blackberry bushes noted above, there were patches of sumac and several 6 to 8 ft. high oak saplings. Growth adjacent to the right training wall is shown in Photos No. 8 and 9.

3. There are numerous animal holes, believed to be fox and woodchuck, on the downstream slope. One of the holes is shown in Photo No. 2. Since the dam embankment has a

central concrete core wall to rock, animal holes should not endanger the embankment.

4. A few 2-man size stones have been plucked from the upstream stone paving, right of the spillway.

5. Considerable seepage occurs through the masonry wall at the downstream end of the left training wall, Photos No. 17 and 18. In addition, water was flowing from2 of 3 one to two-inch diameter pipes located at the base of the wall.

C. Appurtenant Structures. The weir, sidewalls and discharge channel walls are all faced with granite masonry. The smooth faced granite masonry at the top of weir exhibited loss of mortar from joints. Vegetation is also prsent in the joints, Photo No. 7. Seepage through the weir, outletting in the upper courses of the quarry faced stone was evident. Water trickling or flowing from the upper joints was noted in more than twelve locations, evident to the unaided eye of the observer standing in the discharge channel below. No leakage was observed to be discharging under full hydrostatic pressure. At and below the point of seepage, on the downstream face, the granite face was wet, moist, stained and contained deposits of efflorescence. These conditions are shown in Photos No. 9, 10 and 11.

Concrete placed to form a transition between the weir and rock surface of the discharge channel has been severely eroded where it has remained in place. Some of the areas have become loose and the concrete displaced into the discharge channel, Photo No. 16.

The left spillway training wall contains three weep holes at the lower end, with the two weepholes closest to the weir discharging water. More water was observed flowing through the joints in the lower portion of the wall than through the weep holes. The seepage, efflorescence and moss growth are primarily in the lower regions of the wall, Photos No. 17 and 18.

The right spillway training wall, Photo No. 9, has no weepholes. There appears to be a drain discharging water at foundation level at the junction of this wall and the back wall of the side discharge channel. The wall has moist spots and efflorescence present in the lower regions.

The back wall of the side discharge channel has some vegetation growth in the joints and requires repointing.

The side discharge channel bottom is exposed bedrock. Deeper depressions in the rock have been filled with mortared cut stones. Soil has accumulated in the channel and lush vegetation is present in the form of tall grass, weeds, reeds and brush. At the beginning of this channel, against the right spillway training wall, water is percolating in one spot up from the rock below. The beginning area of the side discharge channel contains considerable rust staining. Rust stains are also present along the channel. Loose rocks and concrete debris from the fillet between the weir and channel are lying in the channel. The outlet channel adjacent to the weir has vegetation growth between the stone paving. The invert stones are in place from the weir to the outlet of the 48-inch discharge pipe. Downstream of this pipe the paving shows some areas of displaced stones. Minor debris is present in the downstream channel. These conditions are shown in Photos 14, 15, 16, 19 and 20.

The control house exterior masonry is in good condition, Photo No. 12. The upper joints in the masonry indicate the loss of some mortar. The windows and doors are in poor condition. The interior main floor of the structure has been modified a number of times. Grating and steel plates cover abandoned openings in the slab. One area of the floor adjacent to a covered opening shows intentional or unintentional distortion. The shafts below the main floor were not available for observation during the inspection. However, the one shaft viewed from the top indicated that the shaft was brick-lined and in good condition (in the upper region).

D. Reservoir Area. The area around Sudbury Reservoir is generally wooded. While some slopes are steep, there is no possibility that landslides into the reservoir would cause waves which would overtop the dam. No conditions which might result in a sudden increase in sediment load into the reservoir were noted.

E. Downstream Channel. The channel immediately downstream of the spillway is in satisfactory condition. The floor of the side channel is irregular bedrock with a considerable cover of brush, Photos No. 14 and 15. While some paving stones have been displaced in the channel immediately downstream of the left end of the spillway, Photos No. 19 and 20, the floor is generally in good condition. A low masonry wall on the left side of the channel and a paved slope and ma-

sonry wall on the right, extend a short distance downstream of the roadway bridge, Photos No. 21 and 22. Conditions further downstream are shown in Photo No. 21.

3.2 EVALUATION

Based on the visual examination during the site visit on 30 June 1978 the dam and appurtenant structures are in good condition with the exception of the observed line of seepage approximately 10 ft. below the spillway crest and a few minor deficiencies as described in Section VII. This seepage line may indicate the presence of a crack through the spillway which would be a concern. Otherwise, the minor deficienies noted require long term action and should not have an immediate effect on the performance or safety of the project.

IV. OPERATIONAL PROCEDURES

4.1 PROCEDURES

In general, the operation of the dam is controlled by instructions from the MDC Framingham office. The operation appears to be based on water demand.

4.2 MAINTENANCE OF DAM

It appears that the dam embankment, the spillway weir and other components of the structure have received little maintenance since about 1956 when the toe of the weir was gunited. The earth embankment has not been mowed for several years.

4.3 MAINTENANCE OF OPERATING FACILITIES

The operating facilities appear to have received maintenance only when such maintenance has become a necessity. The dam supplies water only during periods of high demand, and then the water is discharged into the stream to flow into another reservoir at a lower elevation. All gates and valves in the control house are hand operated. There are no gauges or indicators present in the building. Electric power to or from the structure has been discontinued.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

There is no established warning system or emergency preparedness plan in effect for this structure.

4.5 EVALUATION

At least a portion of the control outlets are working, as personnel indicated they had closed the outlets approximately one week prior to the inspection. Plans of the outlet works should be updated and kept at the site. The amount of leakage by the gates observed during the inspection and the condition of the interior of the control structure indicates that the structure should probably be reconditioned and a periodic maintenance program be instituted. The condition of the side discharge channel and the masonry weir and walls indicate that a periodic maintenance program should be instituted. The embankment slopes should be mowed.

V. HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

A. Design Data. The Sudbury Dam was designed and constructed in the late 1890's by the Commonwealth of Massachusetts Metropolitan Water Works (MDC) to create a water supply reservoir. Some record drawings have been found but no hydrologic data have been located.

1. Recent hydraulic/hydrologic data which have been generated under the Department of Housing and Urban Development Flood Insurance Administration (HUD/FIA) Program is in a preliminary state and is presently unavailable.

2. The recommended test flood for the size (intermediate) and hazard potential (high) classification of this dam is the probable maximum flood (PMF).

B. Experience Data. The PMF was determined by conservatively using the peak flow rate for rolling terrain as developed by the New England Division, Corps of Engineers. The peak inflow PMF of 33,500 cfs was then routed through the reservoir. The resulting maximum reservoir outflow at the Sudbury Dam was determined to be 11,100 cfs.

C. Visual Observations. Since the original construction of the dam, approximately 14 in. of flashboards have been added to the crest of the spillway and are held in place every 10 ft. by hinged iron pins.

D. Overtopping Potential. A stage-discharge relationship was developed for the spillway. The maximum spillway discharge at the top of the dam [El. 260.35 National Geodetic Vertical Datum (NGVD)] is 23,200 cfs. The spillway water surface at the PMF is El. 257.8 (2.5 ft. below top of dam) with the flashboards removed and El. 259.5 (0.8 ft. below top of dam) with the flashboards in place. Therefore, the spillway is adequate for the test flood.

E. Evaluation. Although the spillway is hydraulically capable of passing the test flood, it appears unlikely that the discharge channel immediately downstream of the spillway would be adequate to contain this peak flow. Consequently, some minor flooding would occur,

particularly with regard to the control and treatment facilities belonging to the MDC which are located at the foot of the dam.

Dam failure analysis based on a 40 percent breach width of the earth dam resulted in a peak failure outflow of 232,000 cfs. The watershed downstream of the dam consists of water supply Reservoir No. 3 which is spanned by the Massachusetts Turnpike and regulated by a dam which discharges to Reservoir No. 1. Reservoir No. 1, which is also controlled by a dam, discharges to the Sudbury River which flows through Framingham Center.

Analysis of the first reach from the Sudbury Dam to the Massachusetts Turnpike resulted in an overtopping of the Turnpike with a water-surface elevation in excess of 200.0. At this stage, severe damage and loss of life would occur in the MDC buildings at the foot of the dam and in newly constructed residences (not shown on present USGS Quadrangle) along Thomas Drive and in the new development located between Reservoir No. 3, Route 30, Route 90, and Marist College.

In conclusion, the spillway is adequate to pass the test flood (both gated and ungated) and in the event of a dam failure, a high hazard exists for loss of life in many homes located between the dam and the Massachusetts Turnpike.

VI. STRUCTURAL STABILITY

6.1 EVALUATION OF EMBANKMENT STRUCTURAL STABILITY

A. Visual Observation. Although the embankment slopes were difficult to examine due to vegetation, there was no visible evidence of embankment instability during the site examination on 30 June 1978. There was no evidence of erosion or piping where seepage occurs at the downstream toe left of the spillway. Therefore, the seepage is not considered to pose an immediate hazard to the stability of the downstream slope.

B. Design and Construction Data. MDC Record Drawings of Sudbury Dam, Appendix B, show the design cross-section for the embankment. However, no other design and construction data are available which would indicate the physical properties of earth fills in the embankment. Therefore, a theoretical analysis of the structural stability of the dam was not possible.

The upstream portion of the embankment is "boulder clay puddle" with two horizontal to 1 vertical slopes and a minor berm. The stability of this 70-ft. high slope during rapid drawdown of the reservoir level is questionable. The downstream section of the embankment is "sand and gravel", having slopes of 2 to 1 and 2-1/2 to 1 with a small berm. In the absence of significant seepage, this slope would be expected to be adequately stable under static loading conditions.

The concrete core wall which separates the two sections of the embankment is founded on bedrock, according to the record drawings. While the condition of the wall is unknown, it is probable that the wall along with the "boulder clay puddle" upstream will effectively control seepage through the embankment. It is probable, therefore, that water in the wet areas which occur downstream of the toe, especially at the left side, originates from bedrock which occurs at shallow depths below existing ground. Some seepage from the rock into the "sand and gravel" of the downstream portion of the embankment is also occurring. The line of seepage appears to be somewhat above the toe. Further evidence of seepage and high water levels left of the spillway is given by seepage through the downstream end of the left training wall, Photo No. 18.

C. Operating Records. There are no records of embankment settlement, lateral movement, pore water pressures or other information from field instrumentation.

D. Post-Construction Changes. It does not appear that there have been any post-construction changes to the dam embankment since it was constructed in the 1890's.

E. Seismic Stability. Sudbury Dam is located in Seismic Zone 2 and in accordance with recommended Phase I guidelines does not warrant siesmic analyses.

6.2 EVALUATION OF SPILLWAY STRUCTURAL STABILITY

A. Visual Observations. There was no visual evidence that movement or distress in the spillway, side discharge channel and control structure has taken place. However, abnormal seepage was observed exiting from the weir crest. In addition, seepage from the lower portions of the side walls indicates that water is present behind these walls.

B. Design and Construction Data. Design data in the form of record drawings of the original construction (dated 1899) are available and some of the drawings for the modification of the control structue were also located.

Calculations based on the original contract drawings indicate that the spillway weir, if in good structural condition, is safe for the PMF. However, a seepage line was observed approximately ten feet from the crest. If a horizontal crack in the weir occurs at this level, the upper portion of the weir should not be considered safe for sliding under PMF conditions.

C. Operating Records. There are no records which would indicate the magnitude and nature of past structural movements, if any. There are no records of uplift water pressures or other information from field instrumentation.

D. Post-Construction Changes. The present spillway was constructed in approximately 1897. Since that time, there have been no major alterations to the spillway. The placement of a concrete transition at the toe of the weir in about 1956 has been reported and the visual inspection tends to confirm that the work was performed. The outlet structure was modified in about 1915 to generate electricity and later on to remove the generation equipment.

E. Seismic Stability. The top of the weir cannot be considered safe for seismic loading until the path of the water surfacing on the downstream face of the dam is determined and its effect on the stability evaluated. The trial section of the weir indicated that the factor of safety against sliding is marginal with uplift pressures and a wave height approaching the PMF level. Wave heights of this magnitude during seismic activity would not be unreasonable.

Since the dam is located in Seismic Zone 2, the spillway as a whole can be considered adequately safe under seismic loadings.

VII. ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 DAM ASSESSMENT

A. Condition. The visual examination of Sudbury Dam and review of available documents, did not reveal any evidence of failure or conditions which would warrant urgent remedial treatment. The project is generally in good condition.

Sudbury Dam is capable of safely passing the test flood, estimated to be 8,100 cfs based on the PMF, without overtopping the dam. Passage of the PMF, however, will result in moderate flooding downstream.

Nevertheless, some maintenance should be performed and additional investigations should be undertaken as outlined hereafter.

B. Adequacy of Information. Generally, available drawings and other information were adequate for the Phase I Investigation. However, there is insufficient information for a detailed evaluation of the stability of the spillway weir and of the downstream embankment slope left of the spillway, for static loads and forces due to earthquakes.

C. Urgency. The recommendations for additional investigations and remedial measures outlined in Sections 7.2 and 7.3, respectively, should be undertaken by the MDC within 24 months after receipt of this Phase I Inspection Report.

D. Need for Additional Investigation. Additional investigations should be performed by the Owner as outlined in Section 7.2.

7.2 RECOMMENDATIONS

1. An investigation be performed to evaluate seepage and embankment slope stability left of the spillway weir. The investigation should include test borings and installation of groundwater observation wells, after the embankment and area immediately downstream of the toe are cleared of brush and grass and weeds are mowed.

2. A stability investigation of the upper portion of the spillway weir be performed under loading from the test flood and seismic conditions. The visual examination of the spillway weir indicated a line of seepage approximately ten feet down from the crest of the weir. The upper portion of the weir should not be considered safe without a detailed evaluation of the path of the seepage and its effect on the weir stability.

7.3 REMEDIAL MEASURES

A. Alternatives. Not applicable.

B. Operating and Maintenance Procedures. The following remedial work should be undertaken by the MDC, in addition to the investigations outlined in Section 7.2, to correct deficiencies noted during the visual examination:

1. Clear brush and saplings and mow grass and weeds on the embankment at least once a year. Areas which are wet downstream of the toe should also be cleared to allow visual examination.

2. Repoint granite masonry at crest of spillway, on the downstream face of the spillway weir and elsewhere, as required.

3. Renew the concrete fillet between the toe of the weir and rock surface in the side spillway channel.

4. Remove brush and loose rock from the side channel at bottom of spillway weir.

5. Repair and maintain the control house to protect the contained equipment, ensure safety of personnel, ensure the equipment is operational and minimize leakage through the structure.

6. Due to the height of the dam and its "high" hazard potential classification, develop a formal emergency preparedness plan and warning system, in cooperation with local officials in communities downstream of the project.

7. Drawings of the outlet works including outlet pipes, gates, etc. as they presently exist, should be prepared and kept at the dam site. In addition, an O. & M. manual should be prepared to assure that controls will be operated periodically, grass on the embankment will be mowed and other procedures required to maintain the structure in good operating condition will be followed. Funds for the work should be allocated annually by the MDC.

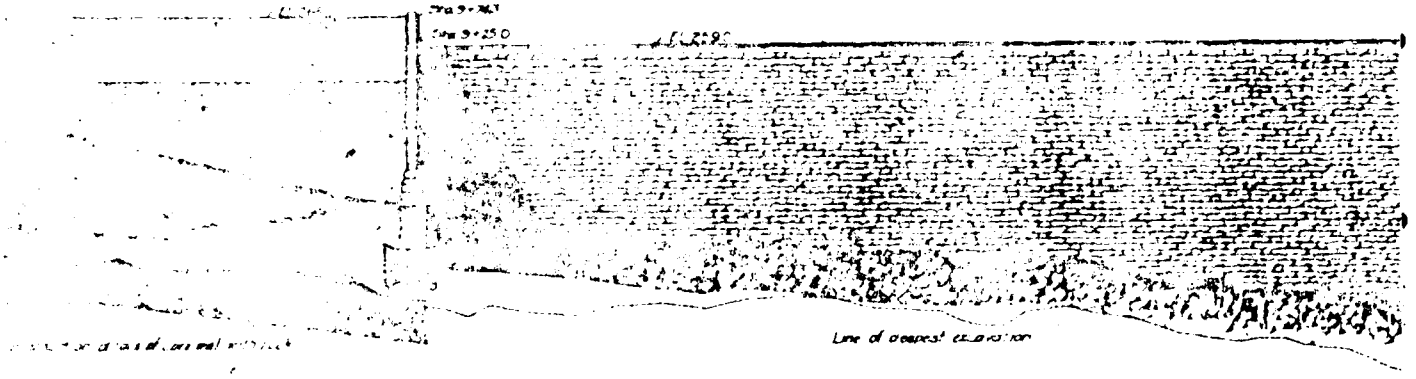
8. Until the recommended investigations are completed, the MDC should provide surveillance of the dam during periods of unusually heavy precipitation and high reservoir levels.

9. Continue periodic inspections on a bi-annual basis.

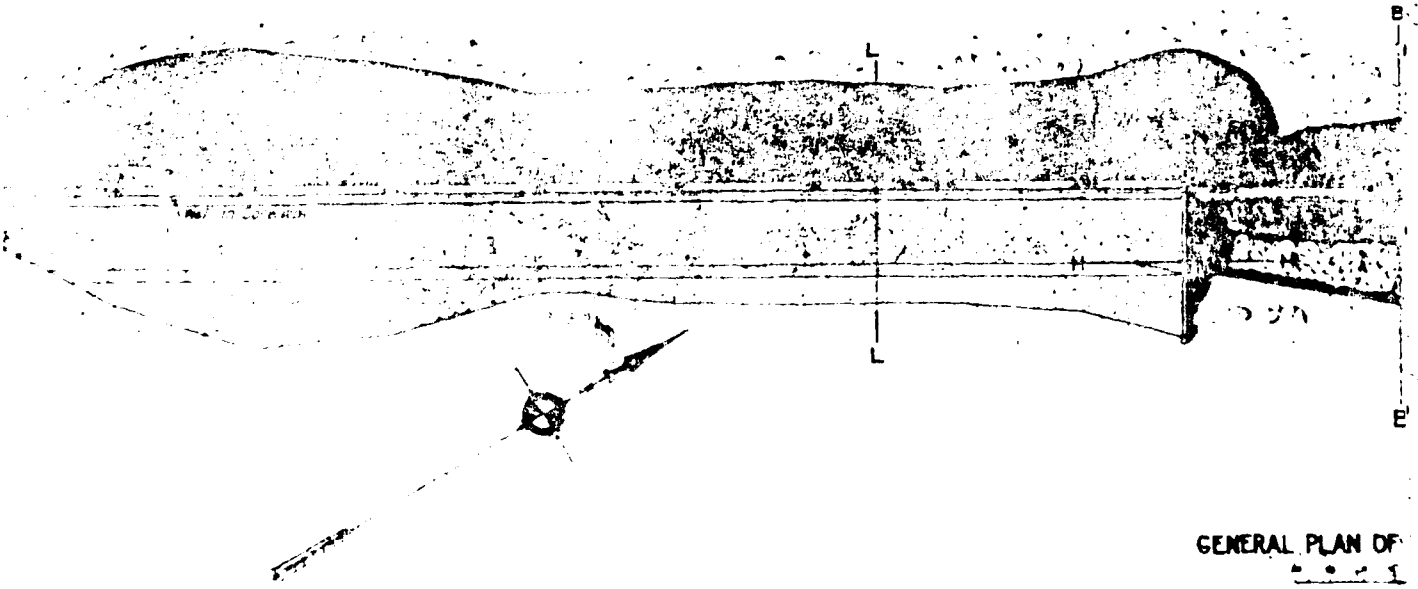
APPENDIX A
INSPECTION TEAM ORGANIZATION AND CHECK LIST

APPENDIX B
LIST OF AVAILABLE DOCUMENTS AND PRIOR INSPECTION REPORTS

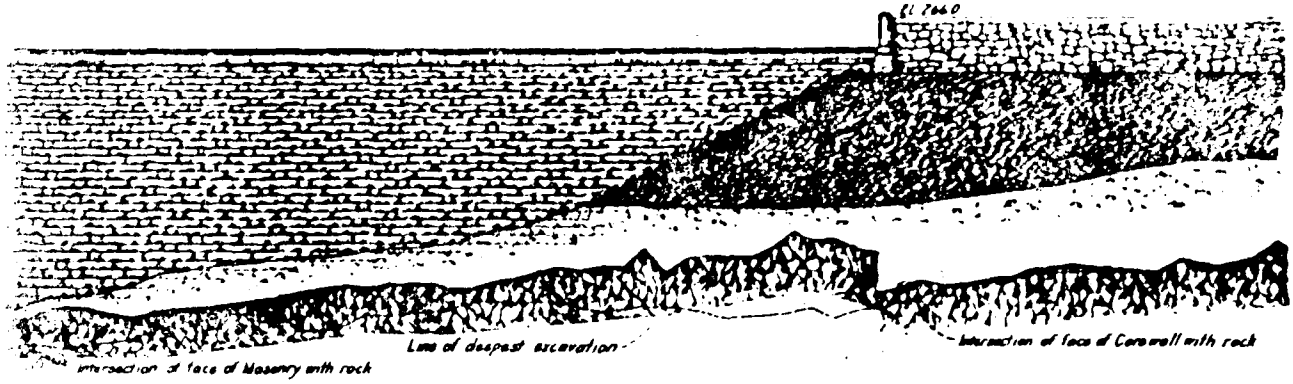
UP STREAM ELEVATI



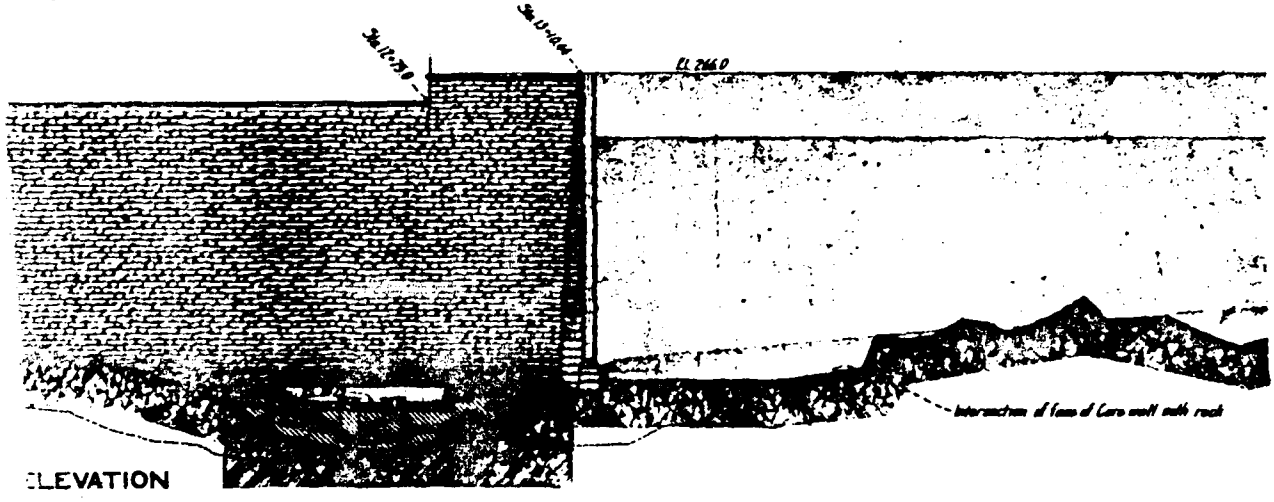
DOWN STREAM ELEVAT



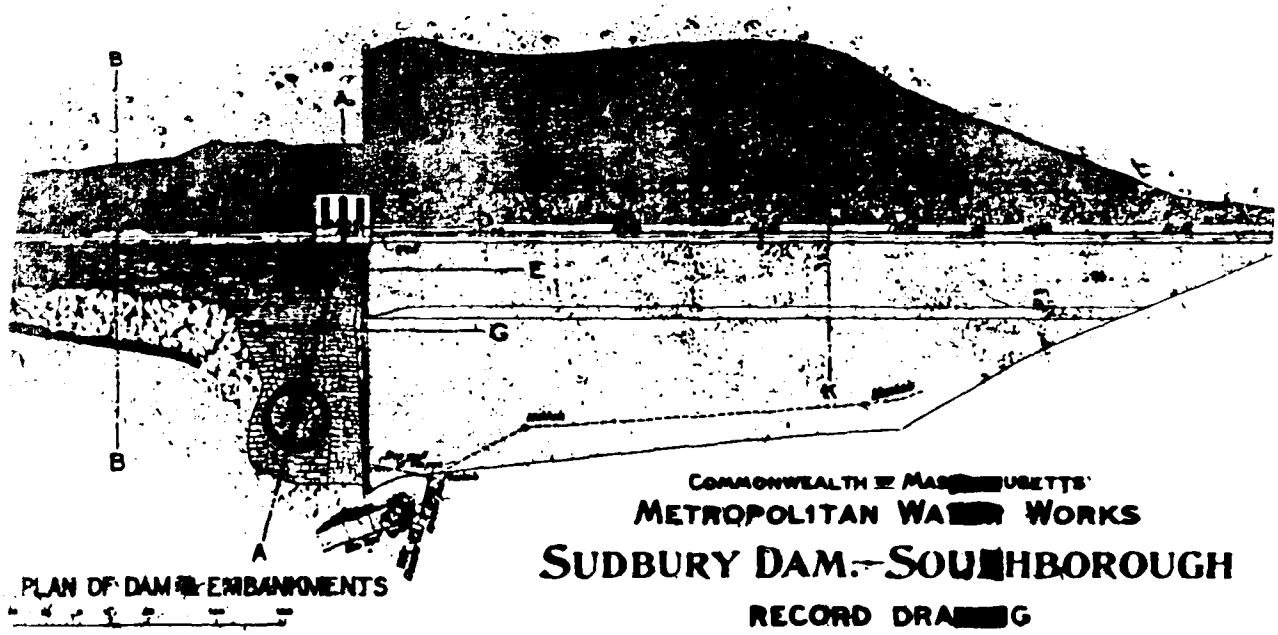
GENERAL PLAN OF



ELEVATION



ELEVATION

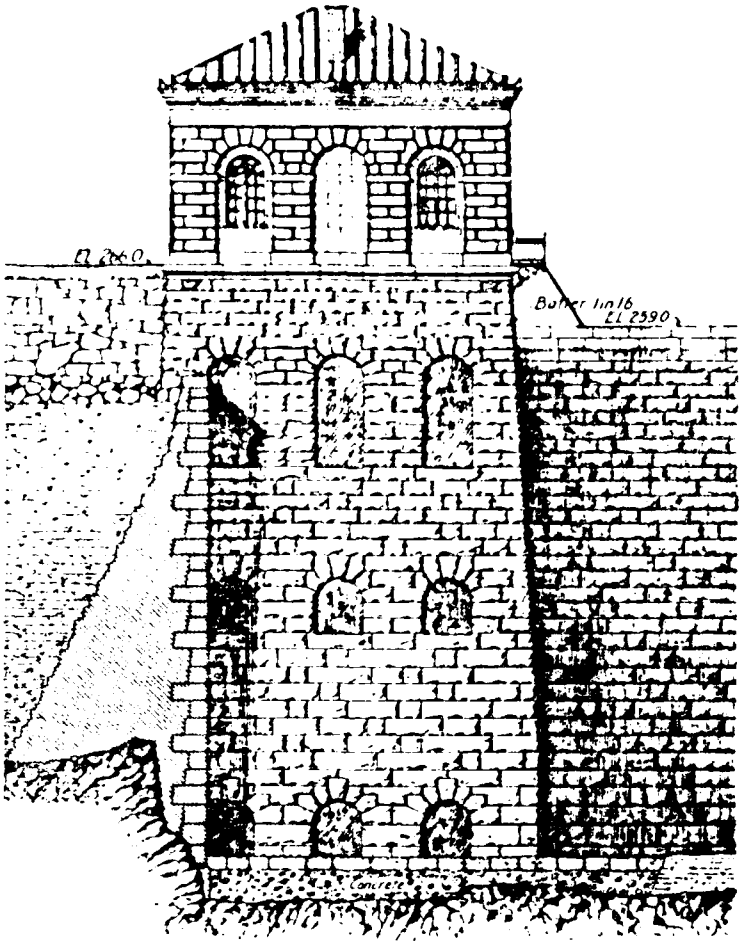


PLAN OF DAM & EMBANKMENTS

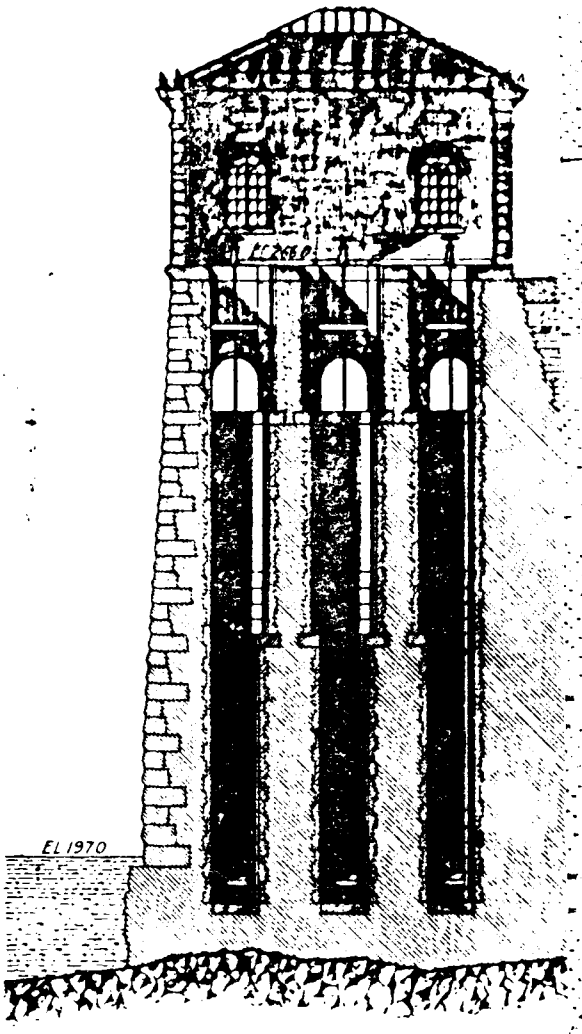
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN WATER WORKS
SUDBURY DAM.—SOUTHBOROUGH
RECORD DRAWING
1939
SHEET NO. 2

APPENDIX B-1

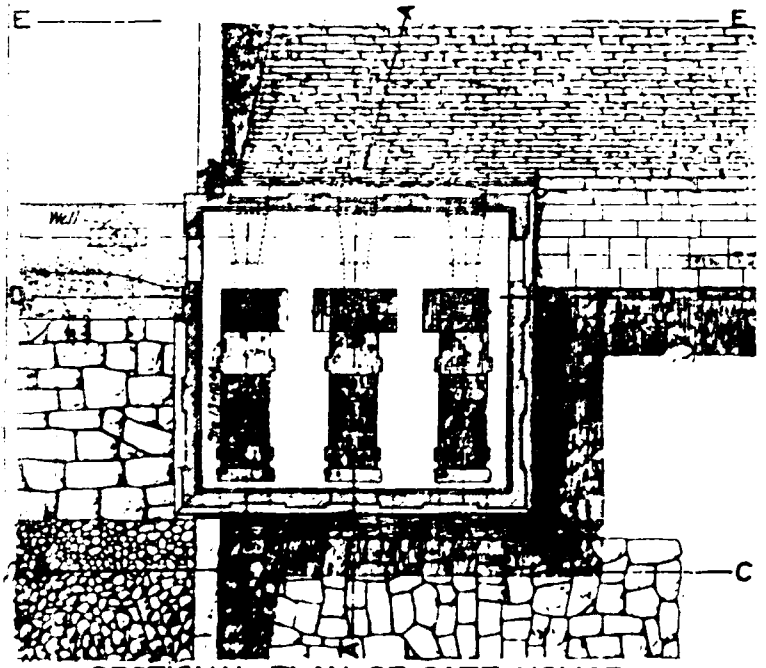
212



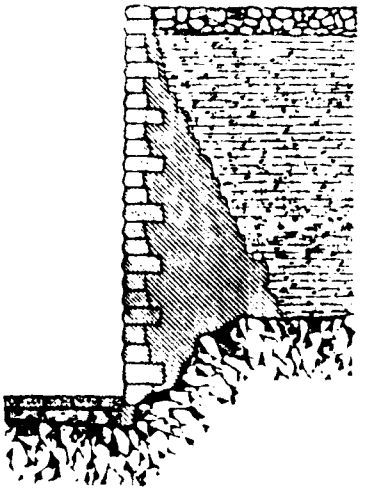
SECTION C-C



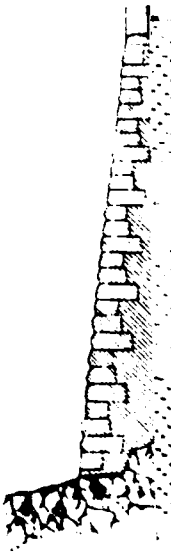
SECTION D-D



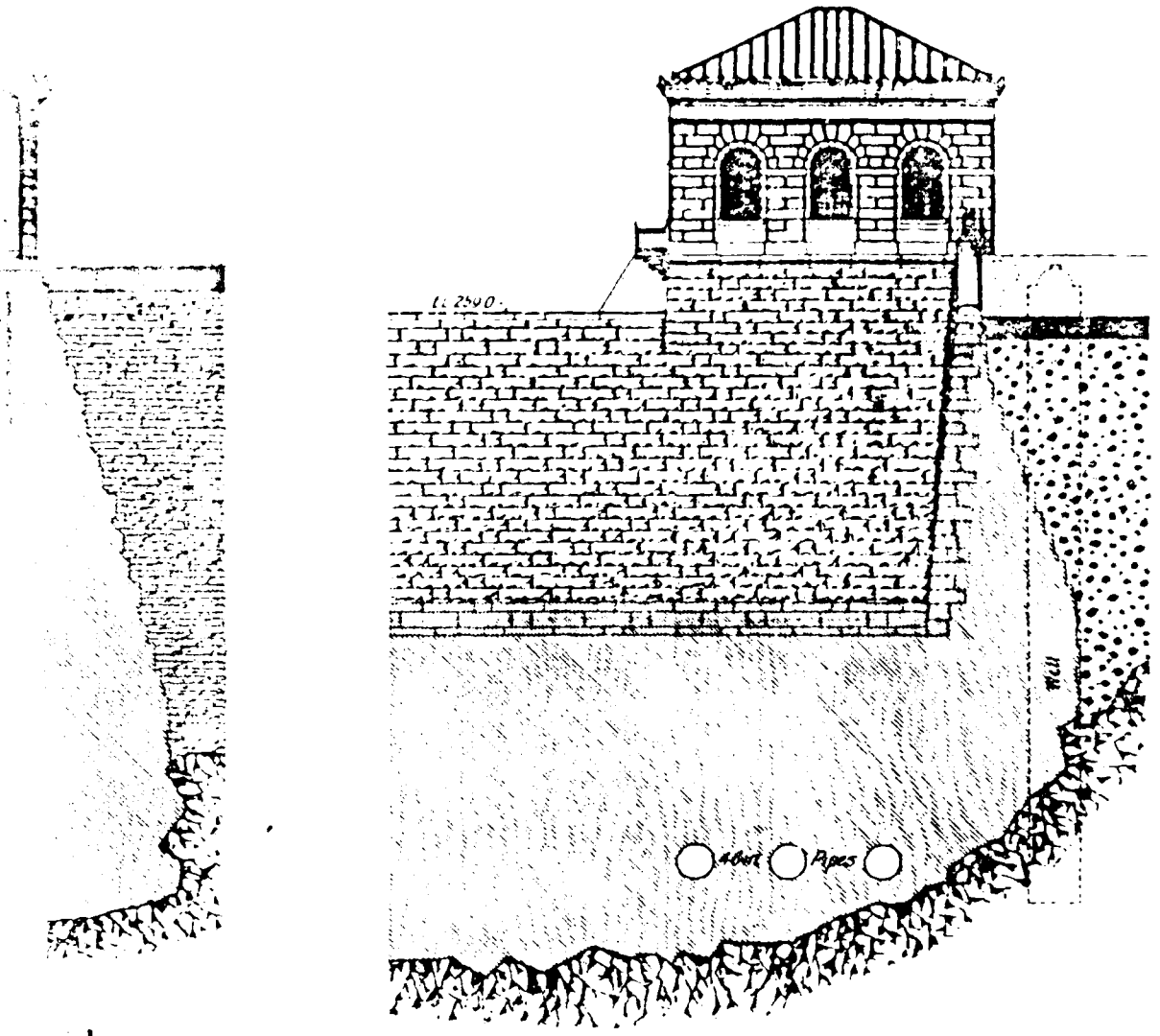
SECTIONAL PLAN OF GATE HOUSE



SECTION F-F

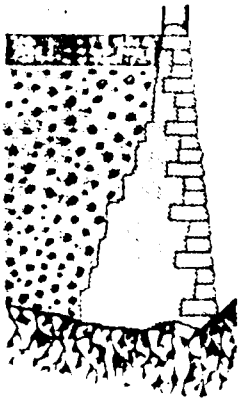


SECTIO



SECTION E-E

CTION G-G



SECTION H-H

COMMONWEALTH OF MASSACHUSETTS

METROPOLITAN WATER WORKS

SUDBURY DAM

SOUTHBOROUGH

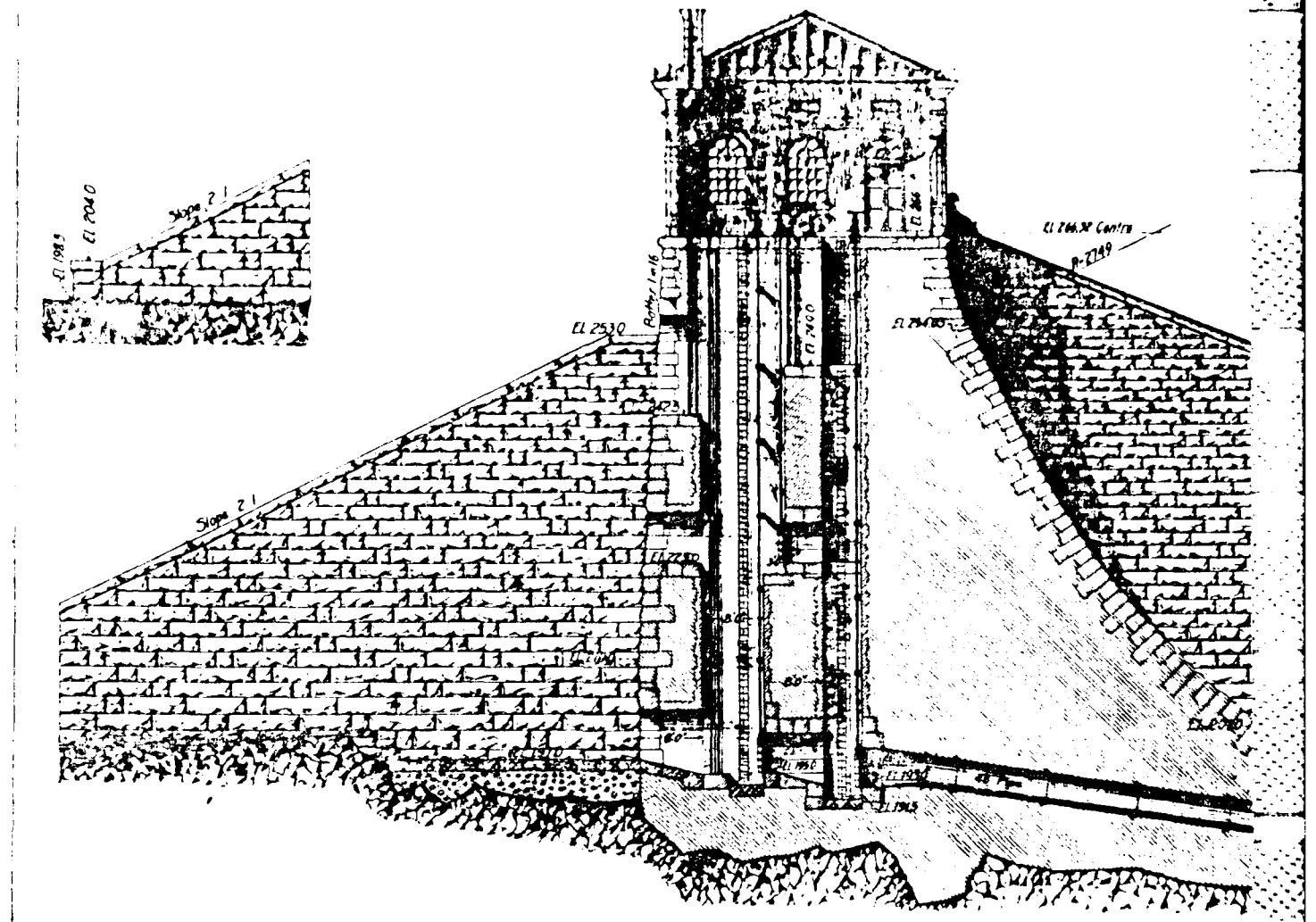
RECORD DRAWING

0 8' 16' 24'

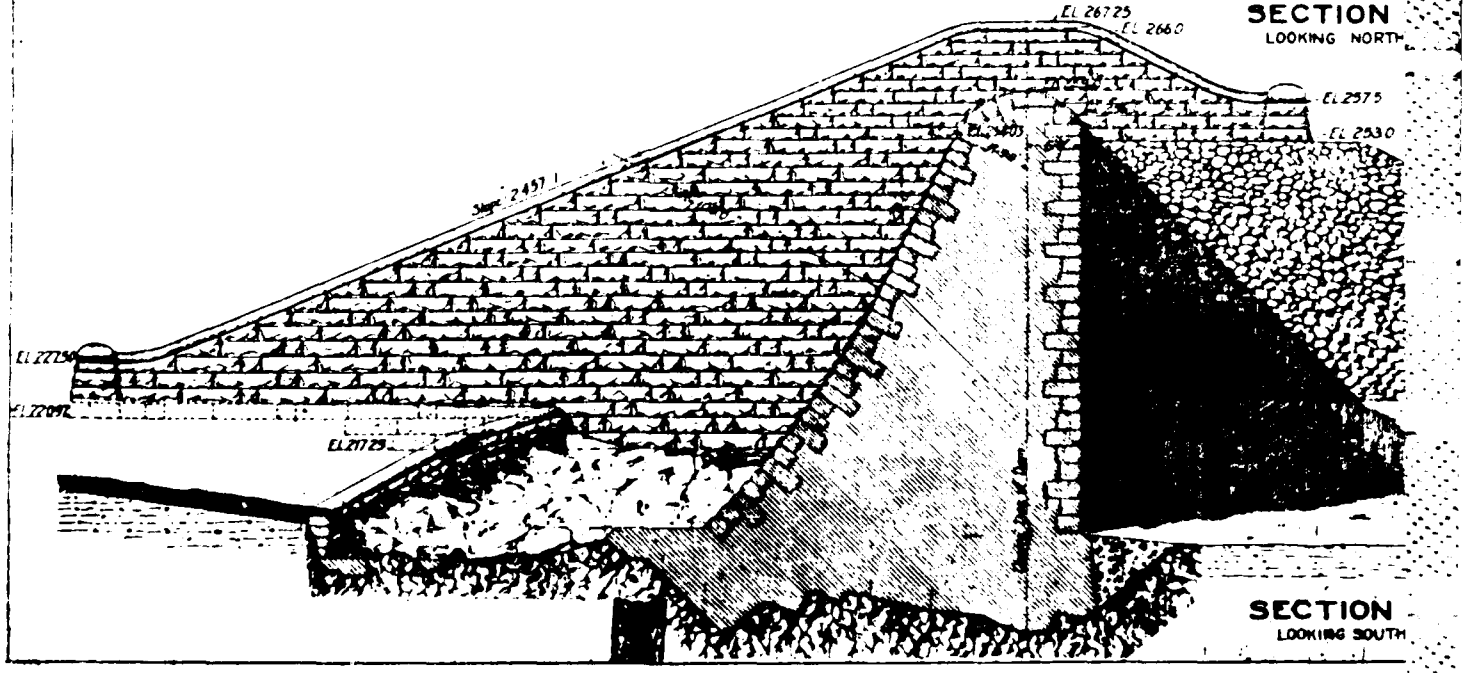
· 1899 ·

SHEET Nº 3

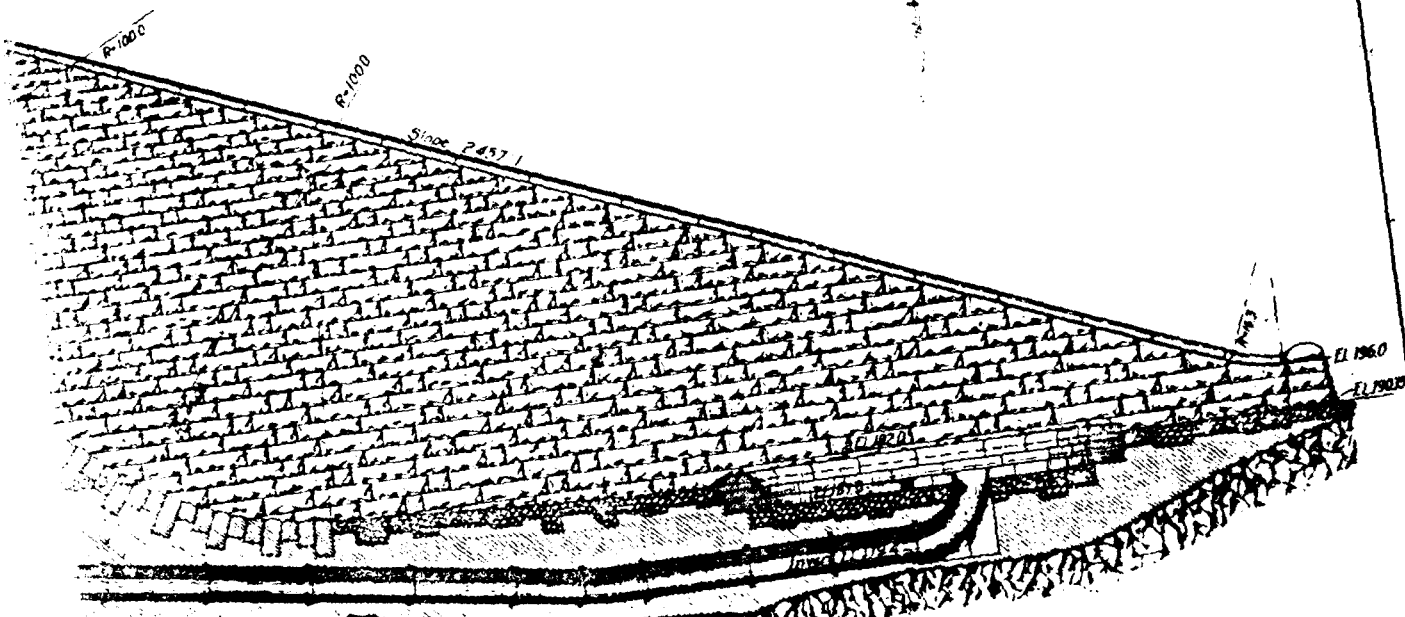
APPENDIX B-3



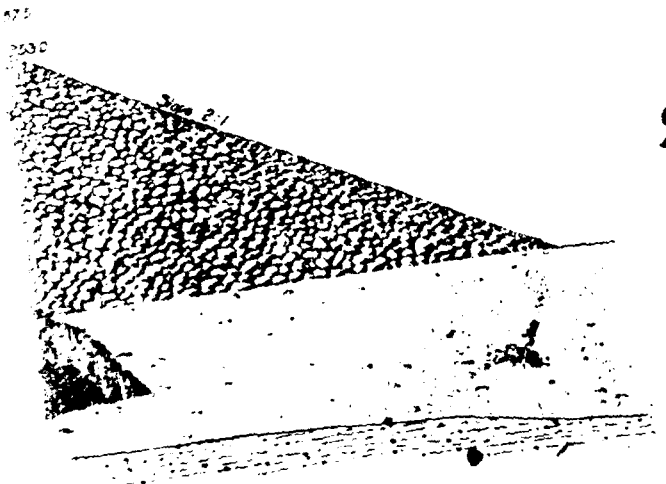
SECTION
LOOKING NORTH



SECTION
LOOKING SOUTH



ON A-A
NORTH EAST



ON B-B
SOUTH WEST

COMMONWEALTH OF MASSACHUSETTS

METROPOLITAN WATER WORKS

SUDBURY DAM

SOUTHBOROUGH

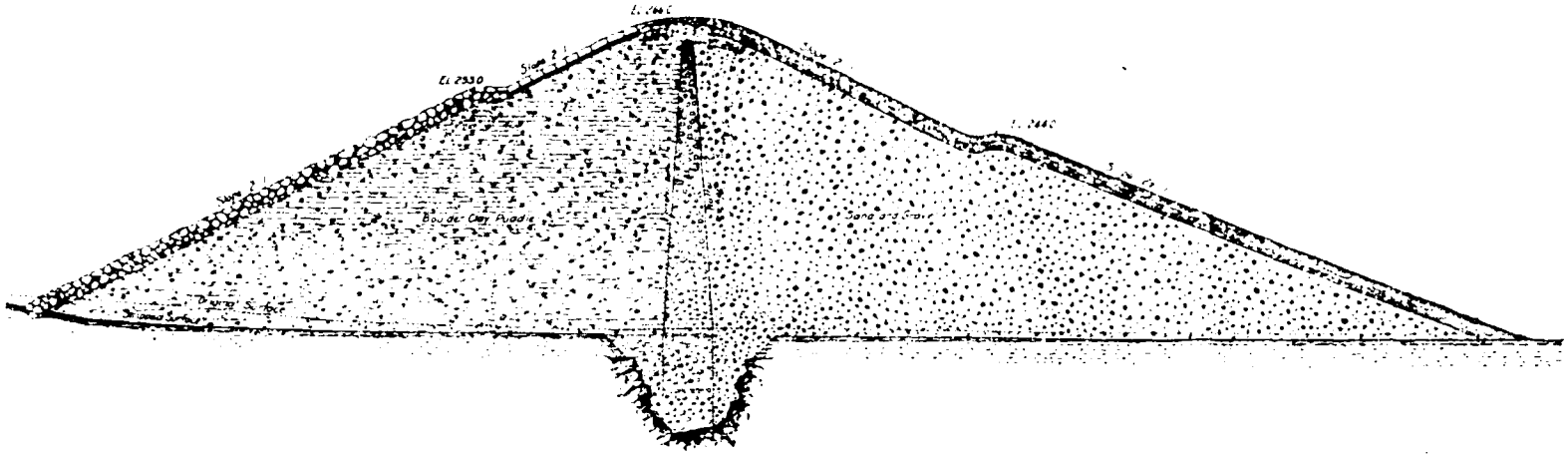
RECORD DRAWING

0 8 16 24

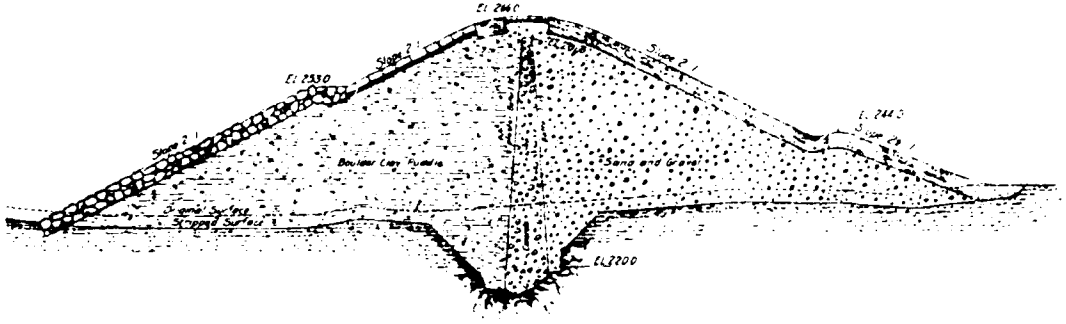
· 1899 ·

SHEET NO. 2

APPENDIX B-2



SECTION K-K



SECTION L-L

COMMONWEALTH OF MASSACHUSETTS

METROPOLITAN WATER WORKS

SUDBURY DAM

SOUTHBOROUGH

RECORD DRAWING

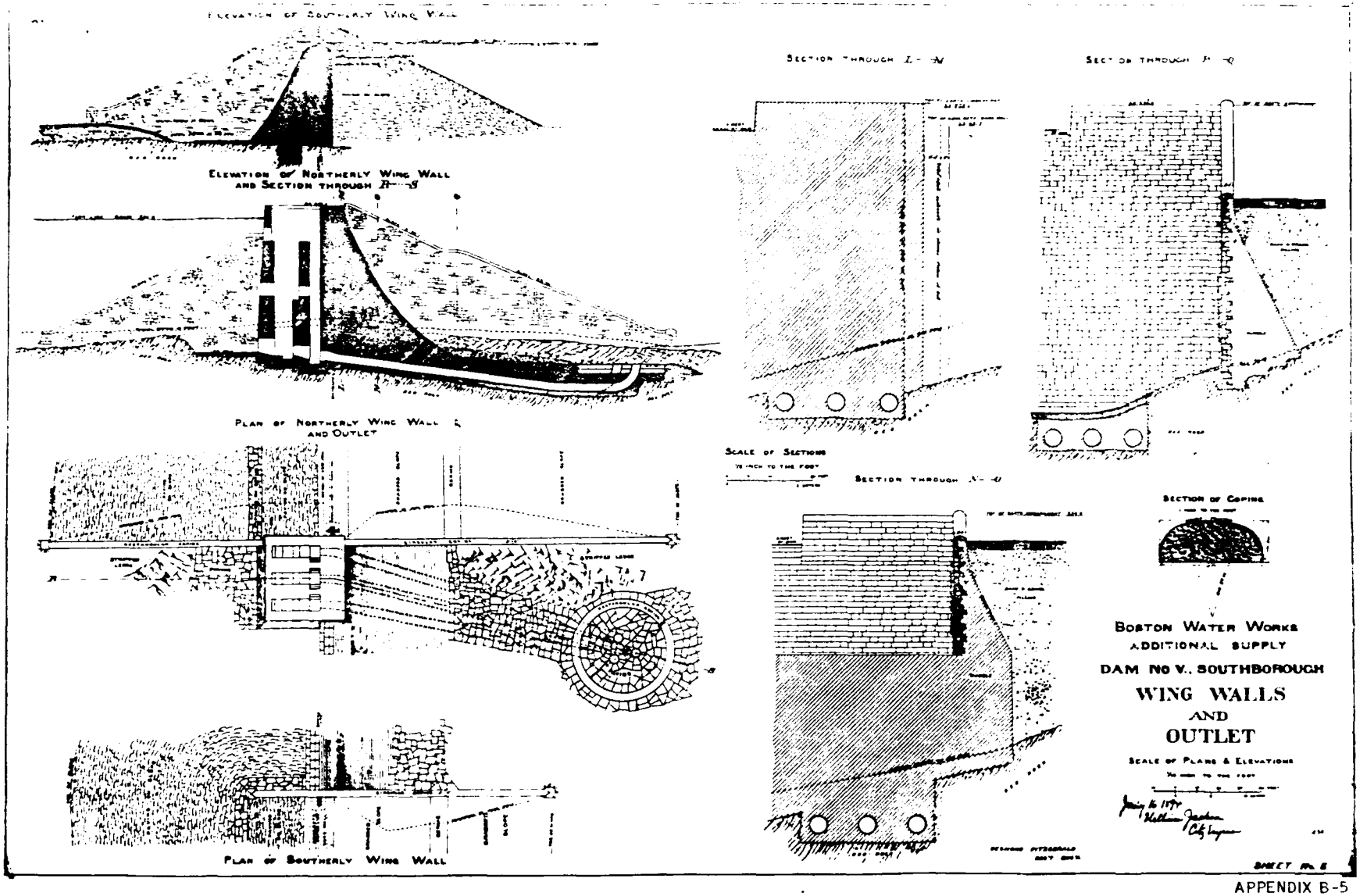
C F H M

· 1899 ·

FILE 4160 86

SHEET No 4

APPENDIX B-4



FILE 4160 87

APPENDIX B-5

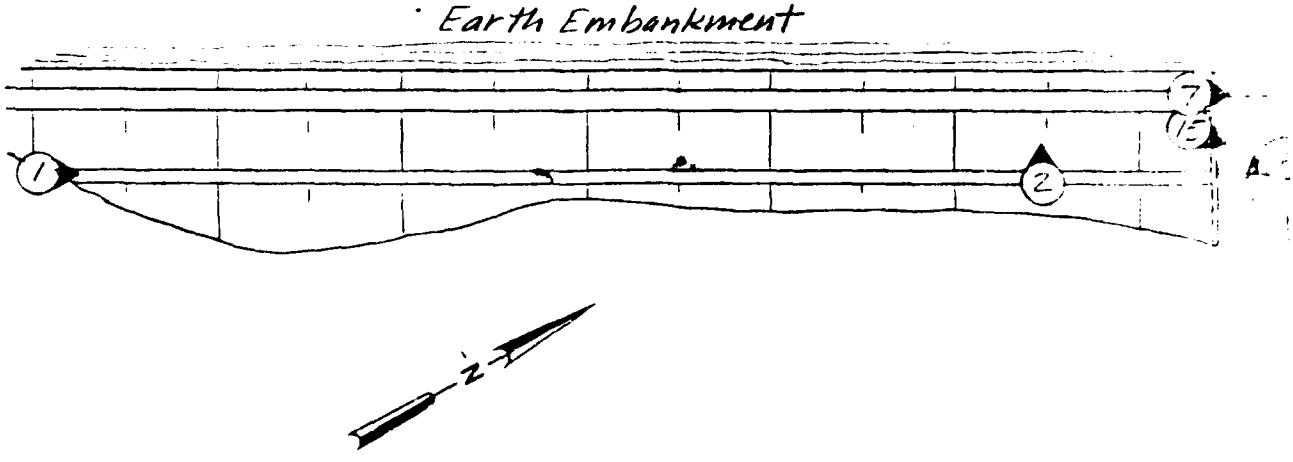
LIST OF AVAILABLE DOCUMENTS
SUDBURY DAM

DOCUMENT	CONTENTS	LOCATION
"Spillway Channel Sudbury Dam", Metropolitan Water Works (MWW), 18 October 1898	Elevation and sections of spillway channel and stone masonry wall	MDC, 20 Somerset St., Boston, MA
"Sudbury Dam - Southborough", MWW, 1899	Record drawings showing elevations, plans and sections of dam and appurtenances (5 sheets)	MDC, 20 Somerset St., Boston, MA (Appendices B-1, B-2, B-3, B-4, B-5)
"Proposed Arrangement of Hydro-Electric Plant", MWW Drawing C684, 20 April 1915	Profile, sections and plan	MDC, 20 Somerset St., Boston, MA
"Sudbury Dam", MWW Drawing C683, 1 May 1915	Plan showing location of 48-in. pipe from Well "A"	MDC, 20 Somerset St., Boston, MA
"Surge Tanks and Wheel Pits for Weston Aqueduct Service", MWW Drawing C685, 24 June 1915	Sections showing existing structure and changes and additions	MDC, 20 Somerset St., Boston, MA
"Surge Tanks and Wheel Pit for Reservoir No. 3 Service", MWW Drawing C686, 24 June 1915	Sections showing existing structures and changes and additions	MDC, 20 Somerset St., Boston, MA

DOCUMENT	CONTENTS	LOCATION
"Underground Transmission Line", MWW Drawing C700, 19 October 1915	Plan, profile and details	MDC, 20 Somerset St., Boston, MA
"Arrangement of Plant Adopted Dec. 10, 1915", MWW Drawing C710, 14 December 1915	Plan showing three generators, transformers, etc.	MDC, 20 Somerset St., Boston, MA
"Sudbury Reservoir", MWW Drawing C835, undated	Plan, scale 1" = 100'	MDC, 20 Somerset St., Boston, MA
"Repairing Spillways of Sudbury Dam in Southborough and Dams No. 1 and 2 in Framingham", MDC Contract 229, 1956	Contract document for repointing of spillways (no modifications of existing structures)	MDC, 20 Somerset St., Boston, MA
"Dismantling, Removing and Disposing of Machinery from the Sudbury Power Station in Southborough", MDC Water Division Contract 296-W, 1970	Contract document	MDC, 20 Somerset St., Boston, MA

APPENDIX C
SELECTED PHOTOGRAPHS OF PROJECT

SUDBURY



NOTE:

1. Plan developed from Sheet 1, 1899 Record Drawing (Appendix B-1) and from Haley & Aldrich, Inc. field observations on 30 July 1978.

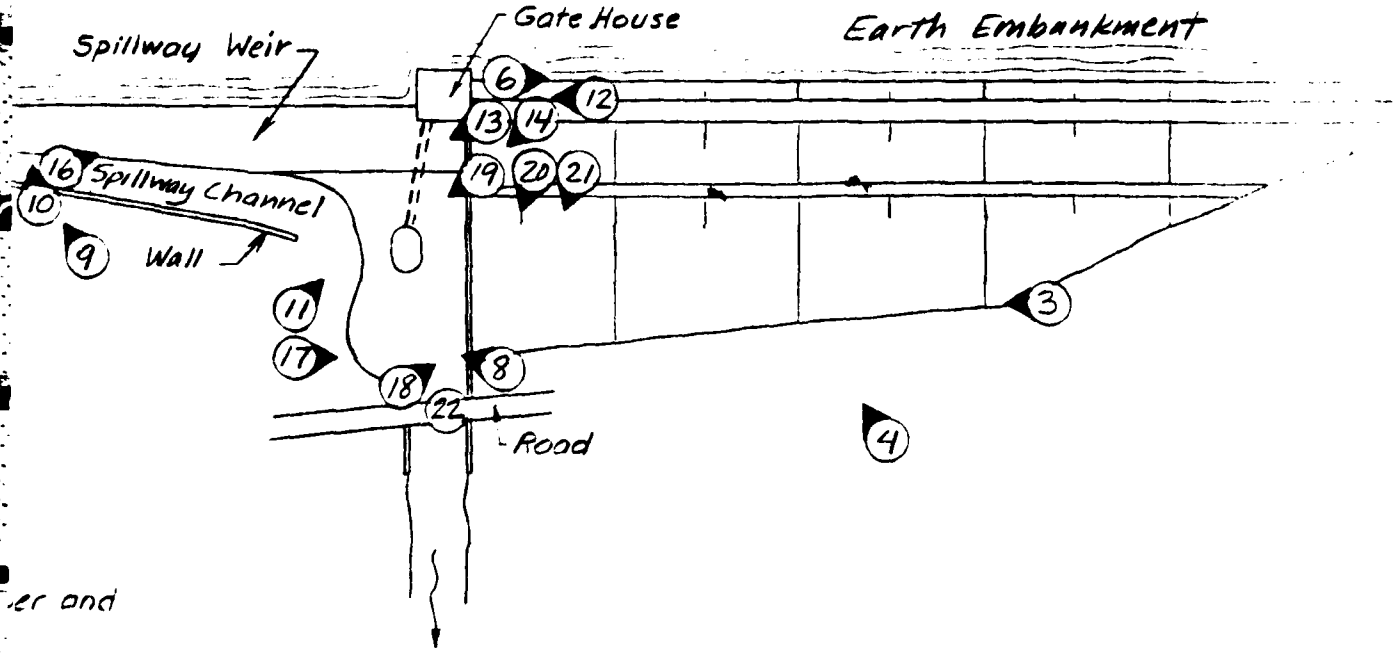
LEGEND:

③ Photograph number and direction of view.

FILE 4160 827

HALEY & ALDRICH INC
CAMBRIDGE MASSACHUSETTS

RESERVOIR



er and

Sudbury Dam
Southborough, MA

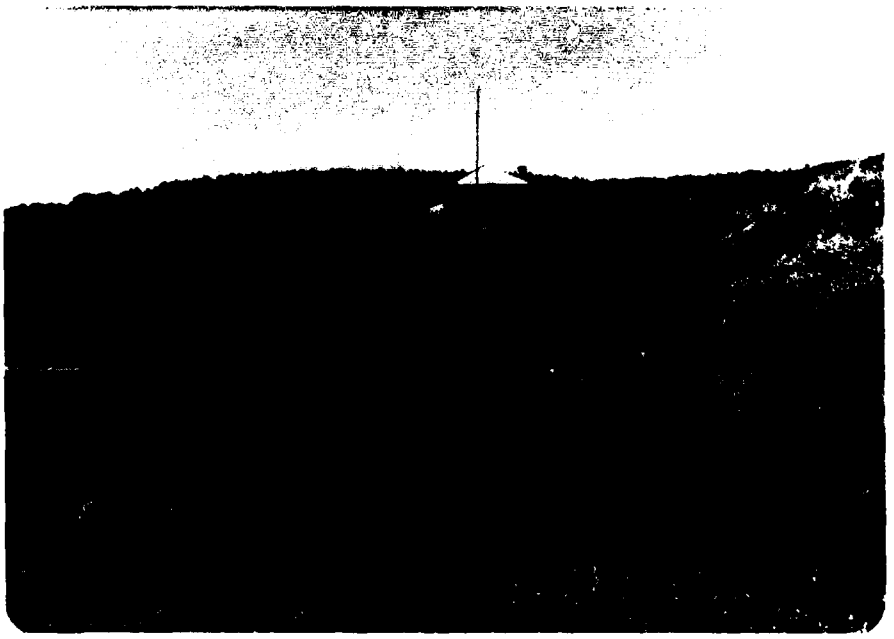
SITE PLAN SKETCH

No scale July 1978

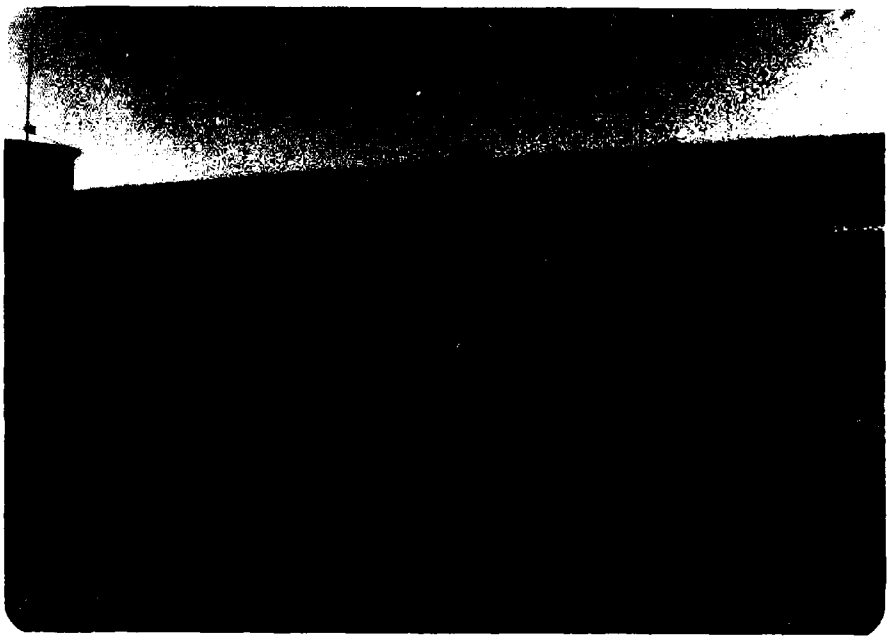
2 of 2

1. Downstream Side of Embankment Right of Spillway, Viewed from Right Abutment

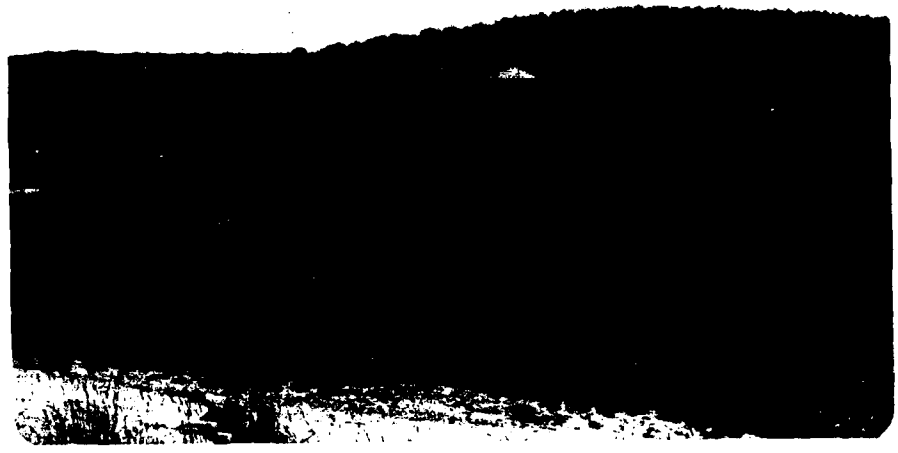
2. Animal Burrow on Downstream Slope



3. Downstream Side of Embankment Left of Spillway



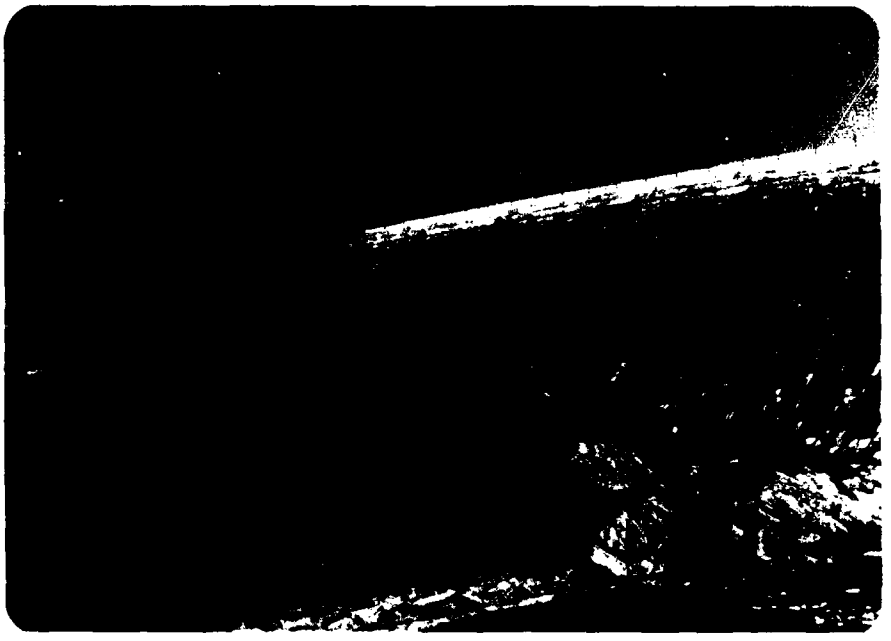
4. Wet Area at Toe of Embankment, Left of Spillway



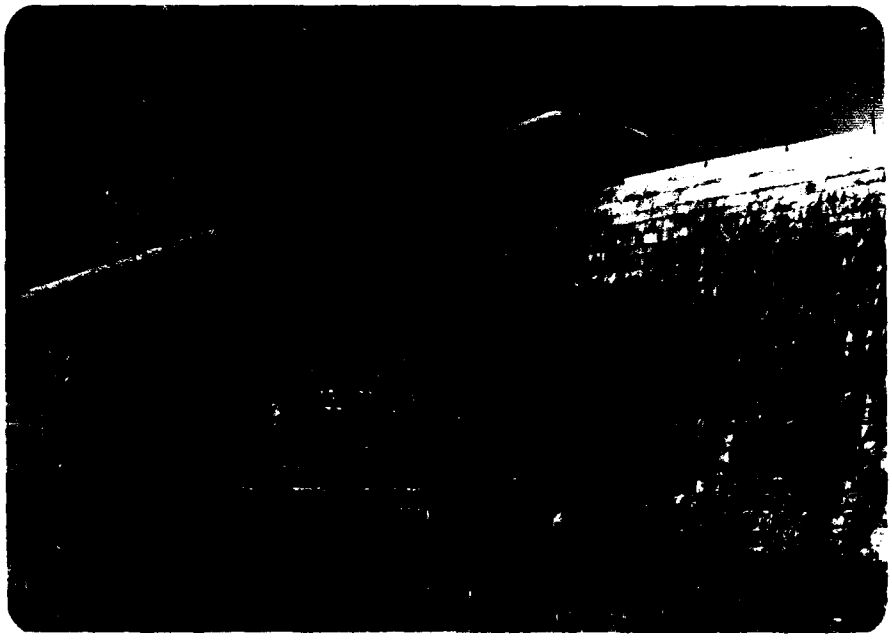
5. Dam and Reservoir, Upstream Side

6. Stone Paving, Upstream Slope

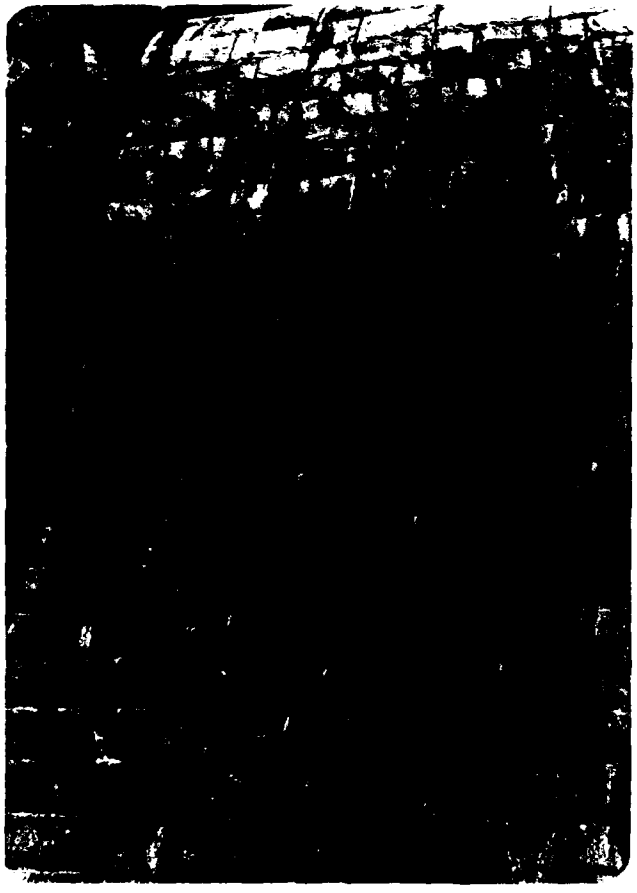
7. Crest of Spillway Weir Showing Flashboards



8. Spillway Weir and Right Training Wall

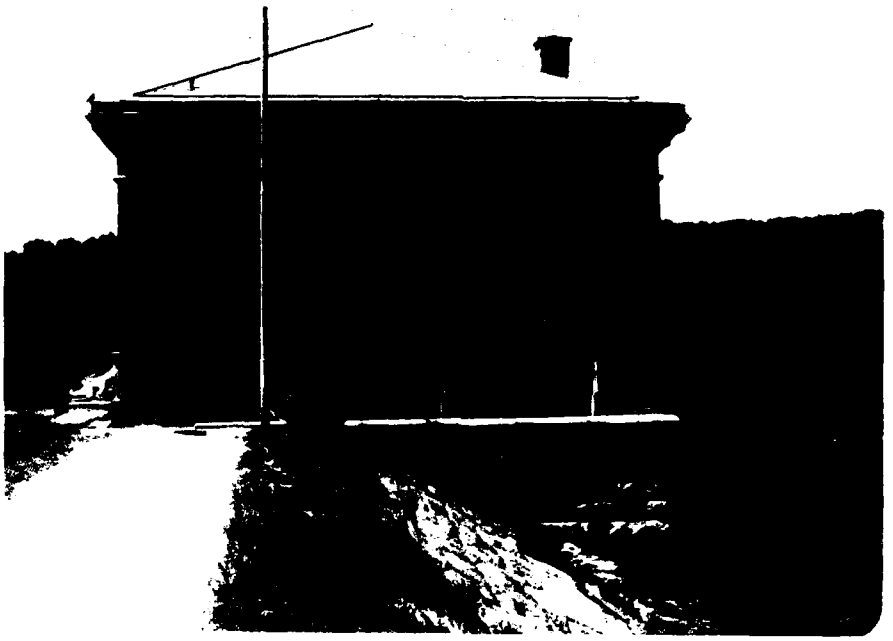


9. Right Training Wall

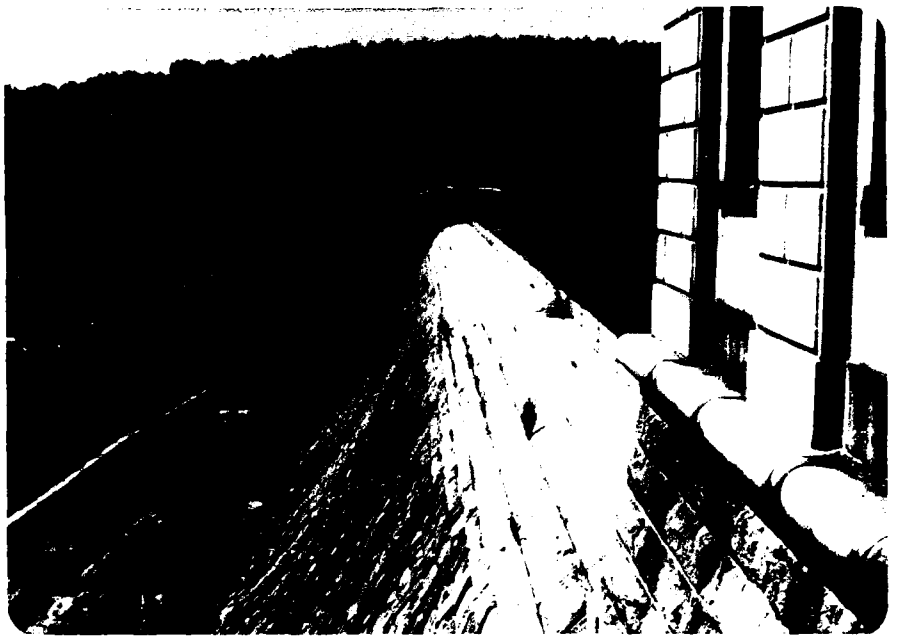


10. Seepage and Staining on Face of Granite, Right End of Spillway

11. Left End of Spillway Weir and Gate House

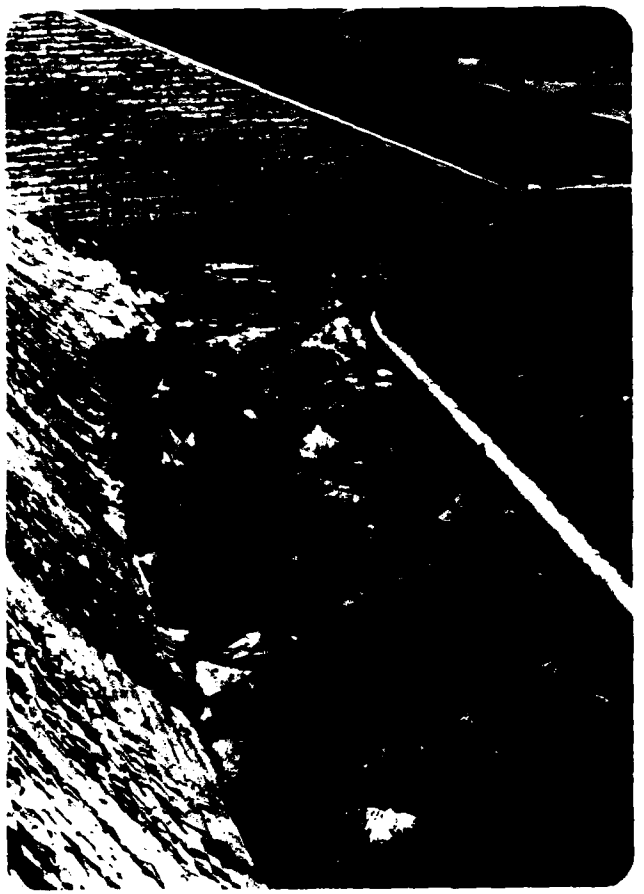


12. Gate House



13. Spillway Weir From Gate House

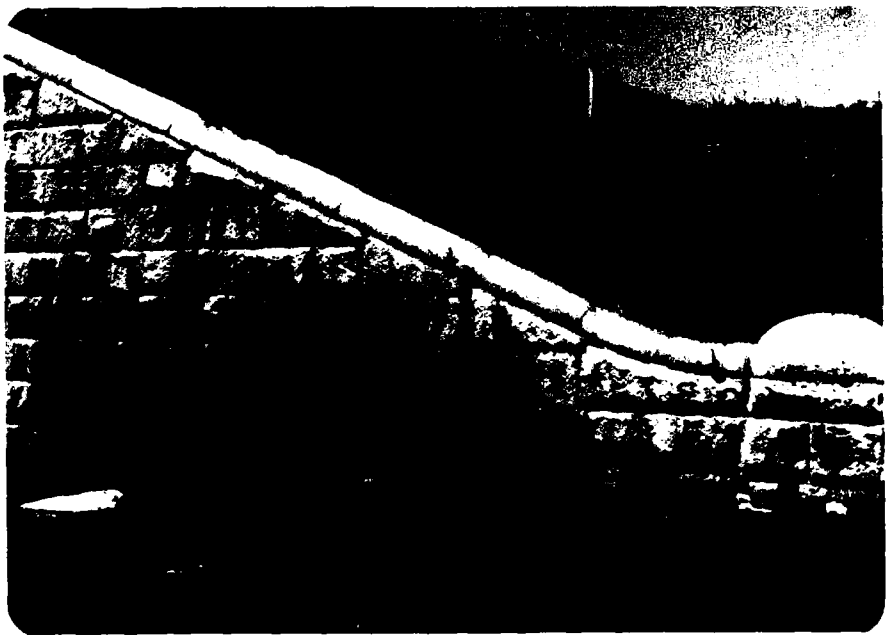
14. Side Channel at Bottom of Weir



15. Side Channel at Bottom of Weir

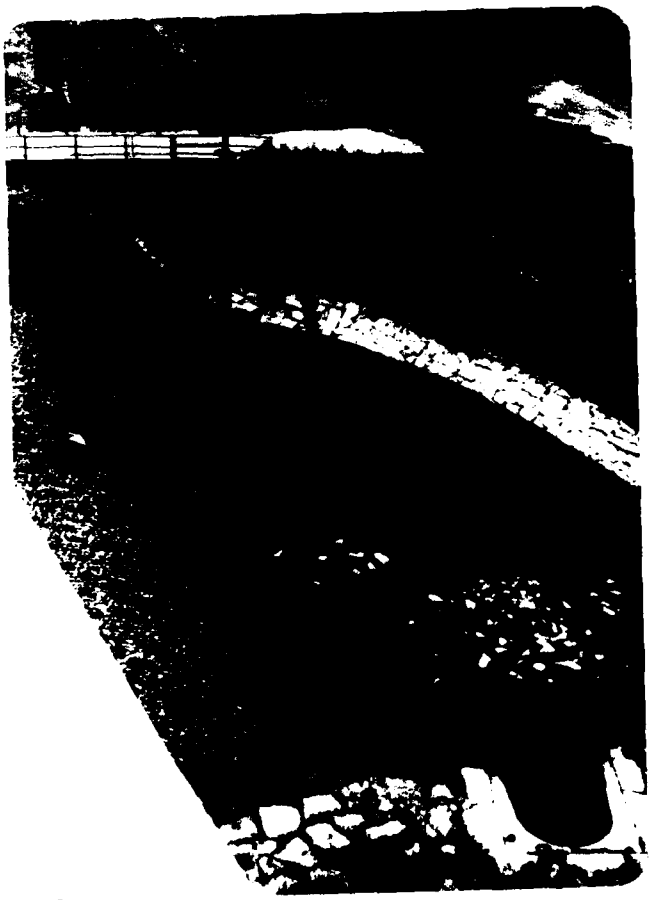
16. Contact Between Bottom of Weir and Rock in Side Channel

17. Downstream End of Left Training Wall

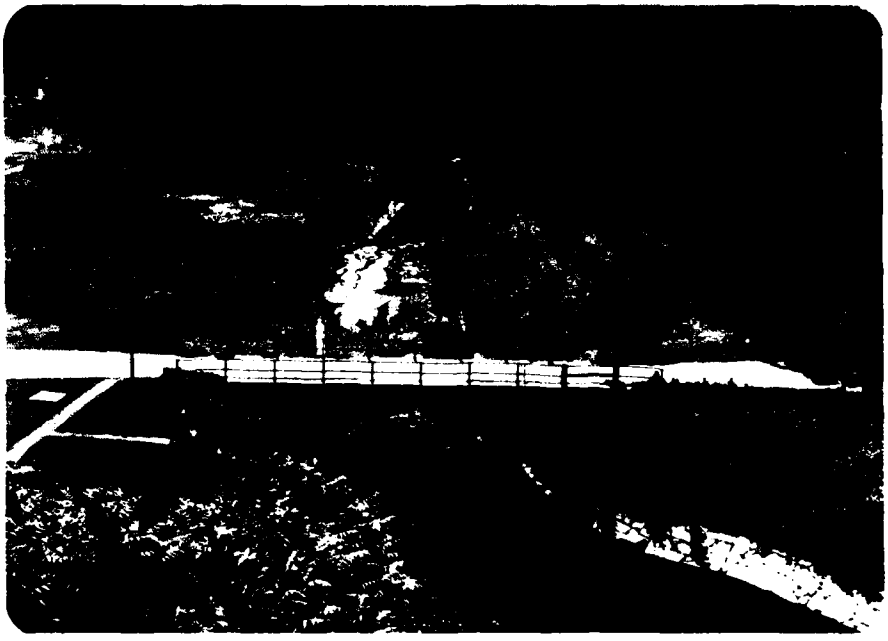


18. Seepage Through Downstream End of Left Training Wall

19. Outlet Structure for 48-inch Pipe and Channel



20. Channel Immediately Downstream of Spillway



21. Channel and Bridge Downstream of Dam

22. Channel Immediately Downstream of Bridge

APPENDIX D
OUTLINE OF DRAINAGE AREA AND HYDRAULIC AND STRUCTURAL STABILITY COMPUTATIONS

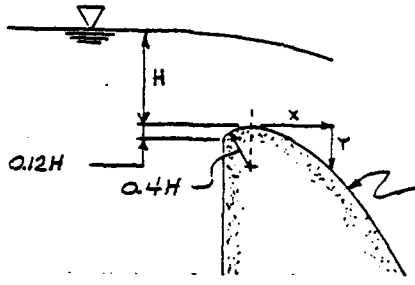
CAMP DRESSER & McKEE Inc. Consulting Engineers Boston, Mass.	N	SUDBURY DAM DRAINAGE AREA SCALE 1: 250 000

APPENDIX D-1

CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

CLIENT HALEY & ALDRICH | JOB NO 561-3-RT | PAGE 1 of
PROJECT SUDBURY RES. DAM | DATE CHECKED 8-21-79 | DATE 7-5-72
DETAIL | CHECKED BY [illegible] | COMPUTED BY ED

STANDARD CREST (King & Brater "Handbook of Hydraulics")

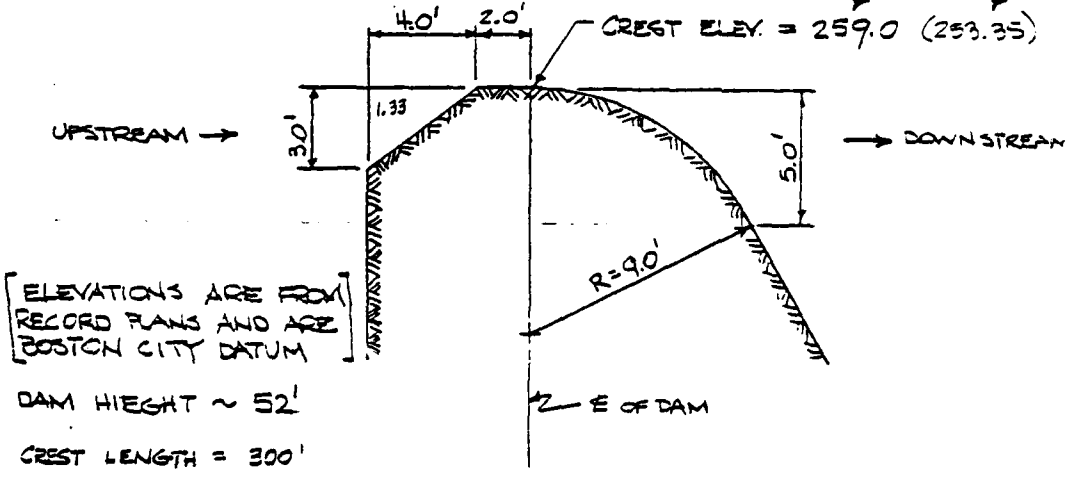


$Q = CLH^{3/2}$

"C" VARIES WITH H

EXISTING CREST (SUDBURY DAM)

BOSTON CITY DATUM ? NGVD ?



[ELEVATIONS ARE FROM RECORD PLANS AND ARE BOSTON CITY DATUM]

DAM HIEGHT ~ 52'

CREST LENGTH = 300'

CREST ELEV. = 259.00

TOP OF SPILLWAY WINGWALLS = 267.25

TOP OF EARTH DAM = 266.00

∴ MAX. HEAD (H) = 266.0 - 259.0 = 7.0'

MAX. HEAD (H) BETWEEN WINGWALLS = 267.25 - 259.0 = 8.25

CAMP DRESSER & McKEE
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CLIENT

PROJECT

DETAIL

JOB NO.

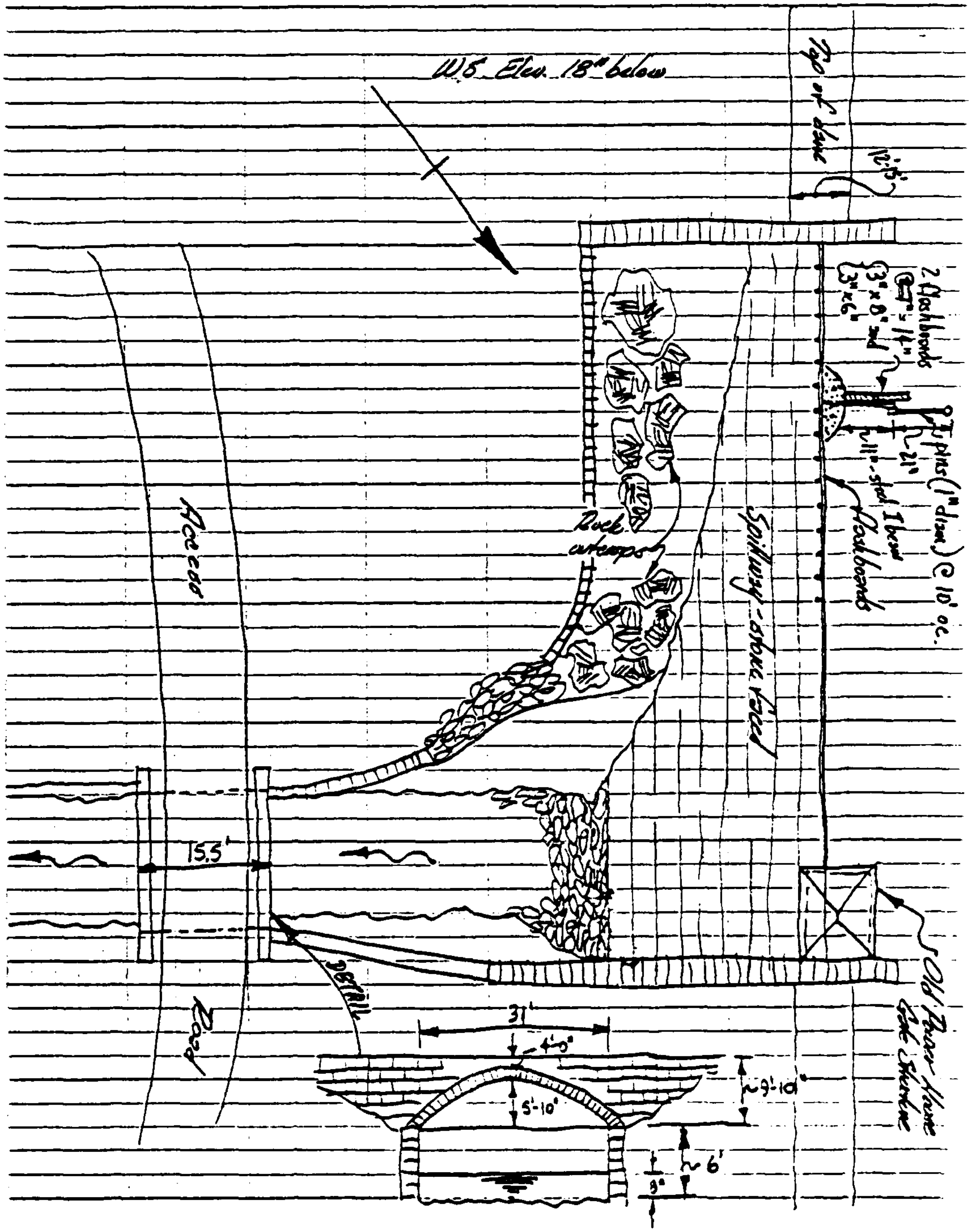
DATE CHECKED

CHECKED BY

PAGE 1a

DATE June 30

COMPUTED BY



CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

CLIENT HALEY & ALDRICH
PROJECT SUDBURY RES. DAM
DETAIL

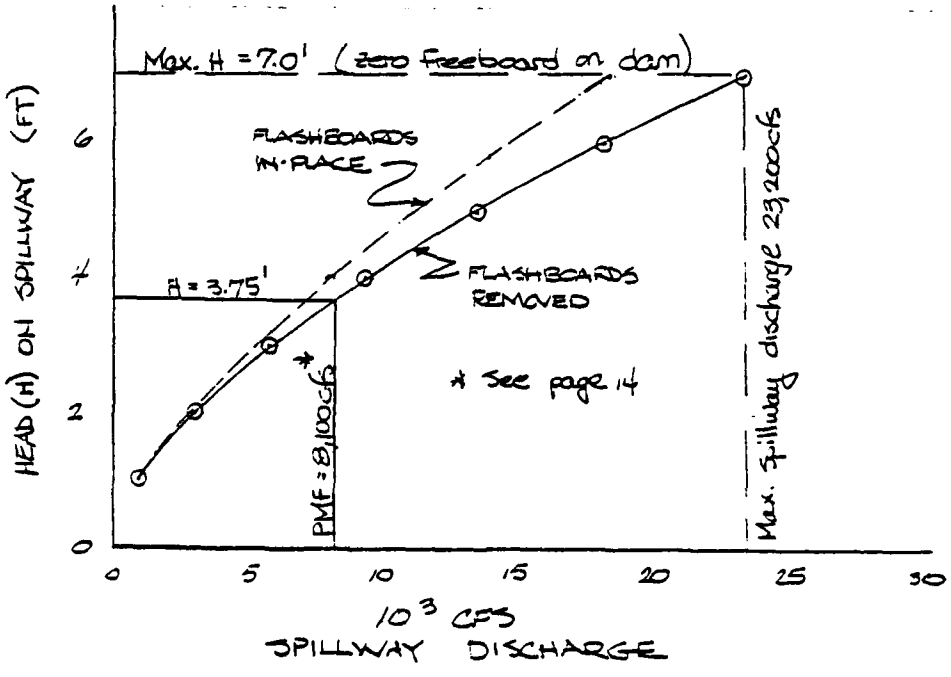
JOB NO 361-9-CT
DATE CHECKED 8-21-78
CHECKED BY

PAGE 2 OF
DATE 7-5-78
COMPUTED BY KD

ASSUME DESIGN CONDITIONS WERE $C_o = 3.8$ @ $H_o = 4.0$ ft.

W.S. ELEV.	HEAD (ft.)	H/H_o	C/C_o	C	Q (cfs)
260.0	1.0	0.25	0.86	3.27	980
261.0	2.0	0.50	0.92	3.50	2,970
262.0	3.0	0.75	0.97	3.69	5,750
263.0	4.0	1.00	1.01	3.84	9,220
264.0	5.0	1.25	1.05	3.99	13,380
265.0	6.0	1.50	1.08	4.10	18,080
266.0	7.0	1.75	1.10	4.18	23,220
267.0	8.0	2.00	1.12	4.26	28,920
267.25	8.25	2.06	1.12	4.26	30,280

BOSTON CITY DATUM



CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

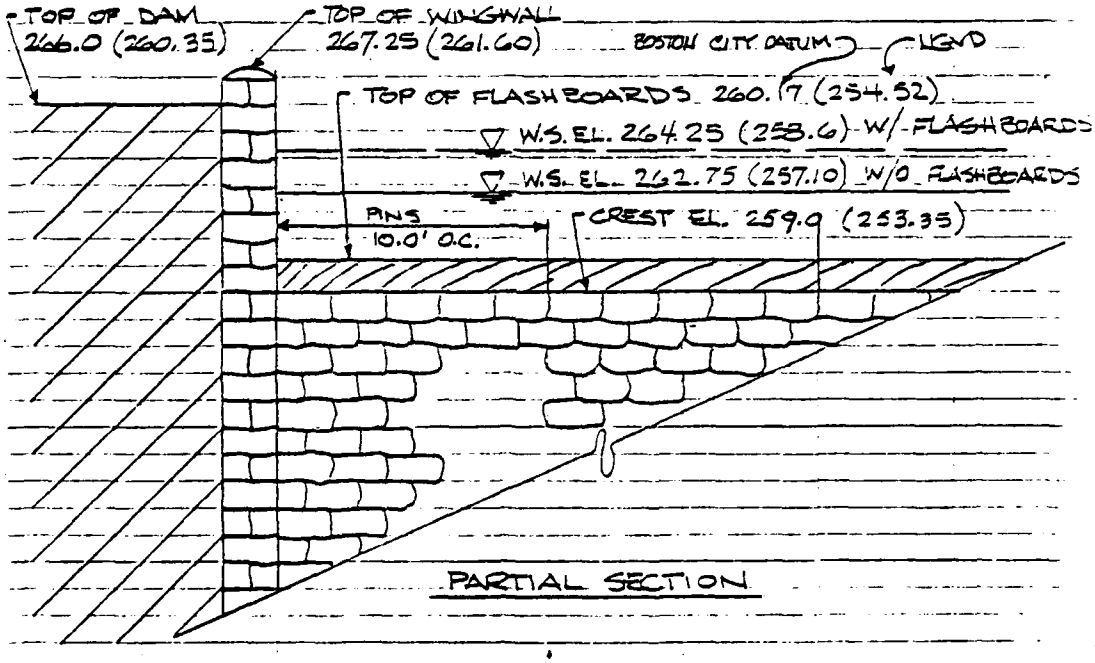
CLIENT HALEY & ALDRICH
PROJECT SUDBURY DAM
DETAIL

JOB NO. 361-8-RT
DATE CHECKED 8-28-78
CHECKED BY

PAGE 2a
DATE
COMPUTED BY JED

ASSUME C= 3.3 WHEN FLASH BOARDS ARE "IN".

W.S. ELEV. (City Datum)	260.0	261.0	262.0	263.0	264.0	265.0	266.0
HEAD (crest)	0.0	0.83	1.83	2.83	3.83	4.83	5.83
FLOW (cfs)	0	750	2,450	4,710	7,420	10,510	13,940



PARTIAL SECTION

CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

CLIENT MERL U.O.T
PROJECT Agency Rd
DETAIL Hydrology

JOB NO 5121-A-RT
DATE CHECKED 8-21-89
CHECKED BY

PAGE 3
DATE 7/5/78
COMPUTED BY JCC

Calculation of PMF

Drainage Area = 22.25 sq. mi.
Rolling Terrain

PMF = 1505 cfs/sq. mi.

∴ PMF = 33,486 cfs

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CLIENT HEALLO - SCOUT JOB NO 561-R-PT PAGE 4
PROJECT Sudbury Res DATE CHECKED 8-21-78 DATE
DETAIL AHA CHECKED BY [illegible] COMPUTED BY

AREA 1

PASS:	AREA:	
	33.79	
1 33.79	33.84	1. 38.25
2 67.63	33.75	2. 76.30
3 101.38		3. 114.59
AVE.	33.79	

AREA 2

38.25	
38.05	
38.29	
38.20	

AREA 3

	49.96
1. 49.96	49.95
2. 99.91	50.07
3. 149.98	
	49.99

AREA 4

1. 33.09	33.09
2. 66.20	33.11
3. 99.32	33.12
	33.11

TOTAL = 155.09 SQ. IN.

$155.09 \left(\frac{2000^2}{5280^2}\right) = 22.25$ SQ. mi.

= 14,242 ACRES FOR SUDBURY RESERVOIR

CAMP DRESSER & McKEE | CLIENT | JOB NO. | PAGE 5
Environmental Engineers | PROJECT | DATE CHECKED 8-21-78 | DATE
Boston, Mass. | DETAIL | CHECKED BY | COMPUTED BY

SUDBURY RESERVOIR

EL. 252

1. 12.12	1. 1.08	~~1.95~~ 1.54	1. 0.03
2. 24.32	2. 2.62	1.34	2. 0.07
Ave. 112.16	3. 3.96		3 0.12
	Ave 1.44		Ave = .04

Newton Is.	Pine Is.	
1. 0.49	1. 0.47	
2. 0.96	2 0.95	Total = 12.71 SQ IN.
3. 1.42	3. 1.40	
Ave 0.47	Ave 0.46	= 1167 A = 1.82 S.mi

EL. 260.0

1. 18.05	1. 1.50	1. 0.18	1. 0.06
2 36.13	2. 3.04	2. 0.30	2. 0.13
Ave. 118.07	+ Ave. 1.52	+ Ave 0.15	- Ave. 0.06

1.	0.27	0.15	0.12
2.	0.57	0.28	0.24
Ave - 0.03	- 0.28	- 0.14 - 0.12	= 19.11 SQ. IN.

= 1755 A
= 2.75 S.m

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CLIENT
PROJECT
DETAIL

JOB NO.
DATE CHECKED
CHECKED BY

PAGE 6
DATE
COMPUTED BY

SUDBURY RESERVOIR

EL. 270

1.	23.45	1.65	0.18
2	46.95	3.26	0.35

Ave. 123.40 + 1.63 + 0.18 = 25.29 SQ. IN.

= 2322 A'
= 3.63 S.M.

Times of Travel

Length in Stream = 16,150'

Length in Reservoir = 6500'

Length in Swamp = 6200'

Length in Overland Flow = 4750'

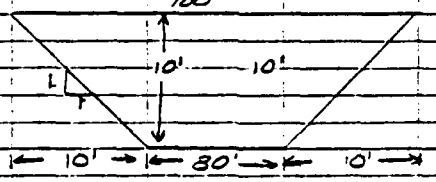
1. Assume stream width = 100'

Slope $\frac{275' - 259'}{16,150'} = \frac{16'}{16150'} = .000991$

$V = \frac{1.486}{n} R^{2/3} S^{1/2}$

Assume n = .030 for natural stream

Area surrounding stream according to U.S.G.S. is by majority steep. Assume side slopes of stream are 2:1



$R = \frac{A}{WP}$ @ depth = 10', $A = 80 \times 10 + 2 \times \frac{1}{2} \times 10 \times 10$

$A = 900$ ft

$WP = 80 + 2 \times 10\sqrt{2} = 108.3'$

$R = \frac{900}{108.3} = 8.31$

$V = \frac{1.486}{.030} (8.31)^{2/3} (.000991)^{1/2}$

$V = 6.9$ f/s

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CLIENT MEA, U.O.T. Group I JOB NO 56179-ET PAGE 8
PROJECT Duxbury Reservoir DATE CHECKED 6-21-79 DATE 7/16/79
DETAIL Hydrology CHECKED BY [illegible] COMPUTED BY dlad

Times of Travel (cont.)

Time in Stream = $\frac{16,150'}{6.9'/s}$ = 2529 s = 42 min

c. Time in Reservoir section (SCS, Section 4, Chapter 15-11)

Assume 10' deep (average)

$V_w = \sqrt{gD_m}$ = $\sqrt{32.2 ft/s^2 \times 10'}$ = 18 ft/s (wave velocity)

Time in Reservoir = $\frac{6500'}{18 ft/s}$ = 361 s = 6 min.

3. Time in Swamp

Assume 2' deep average

Time in Swamp = $\frac{4200'}{\sqrt{32.2 ft/s^2 \times 2'}}$ = 773 s = 13 min.

4. Time for Overland Flow

Since section of area involved in overland flow is < 2000 acres, I'm going to use SCS Fig. 15-2

Slope = $\frac{350 - 280}{4700'}$ = .0149 ≅ 1.5%

Use short grass, pasture cover = 1.9 = 2.6 ft/s

Time for overland flow = $\frac{4750'}{1.86 ft/s}$ = 5523 s = 92 min.

Total Tc = 153 min = 2.55 hrs

Lag = 0.6 Tc = 92 min = 1.53 hrs

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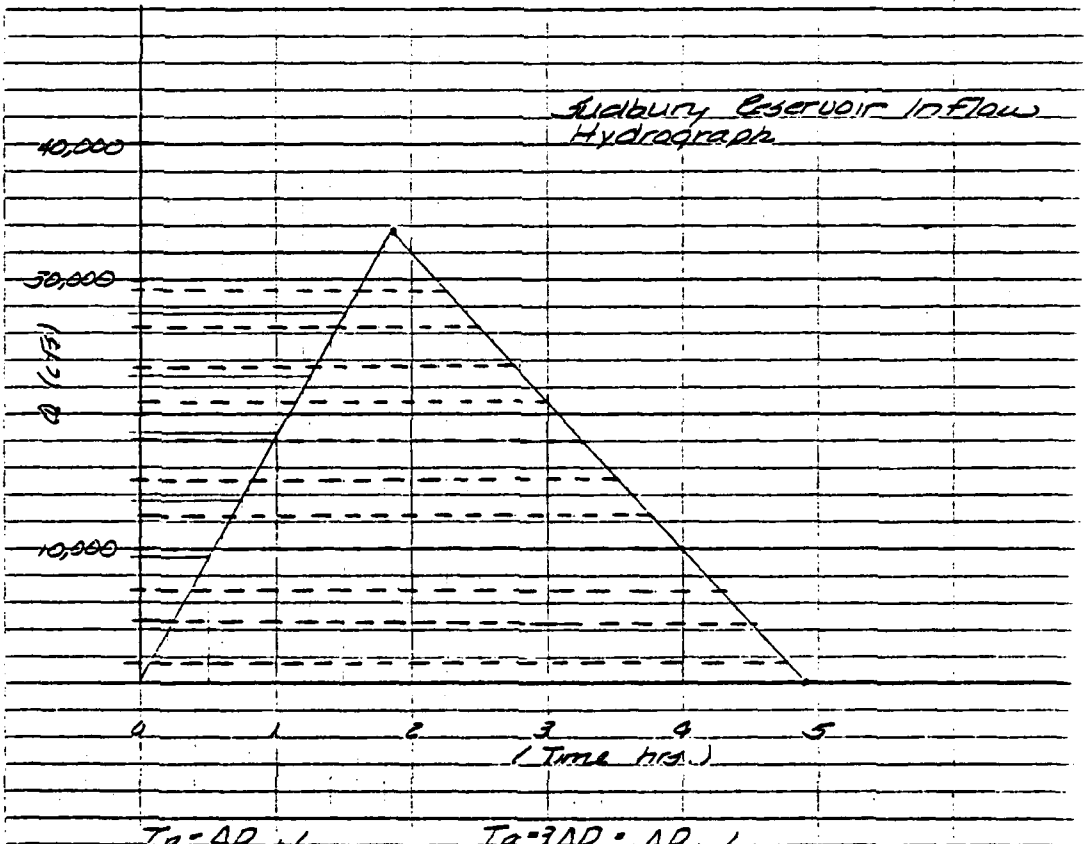
CLIENT MDC A, U.O.I., Group 1 JOB NO. 5141-A-PT
PROJECT Sudbury Reservoir DATE CHECKED 8-21-73
DETAIL Hydrology CHECKED BY [redacted] COMPUTED BY DLod
PAGE 9
DATE 7/24/73

Peak Flow from PMF = 33,986 cfs
occurs @ T = 1.53 hrs

Use Triangular Hydrograph for Inflow Hydrograph



$T_p = \frac{\Delta D}{2} + L$ $T_p = 3\Delta D = \frac{\Delta D}{2} + L$

$T_b = 2.67\, T_p$

$L = \frac{5}{2}\Delta D = 92$ min

$\Delta D = 37$ min

$T_p = 111$ min (1.85 hrs)

$T_b = 295$ min (4.9 hrs)

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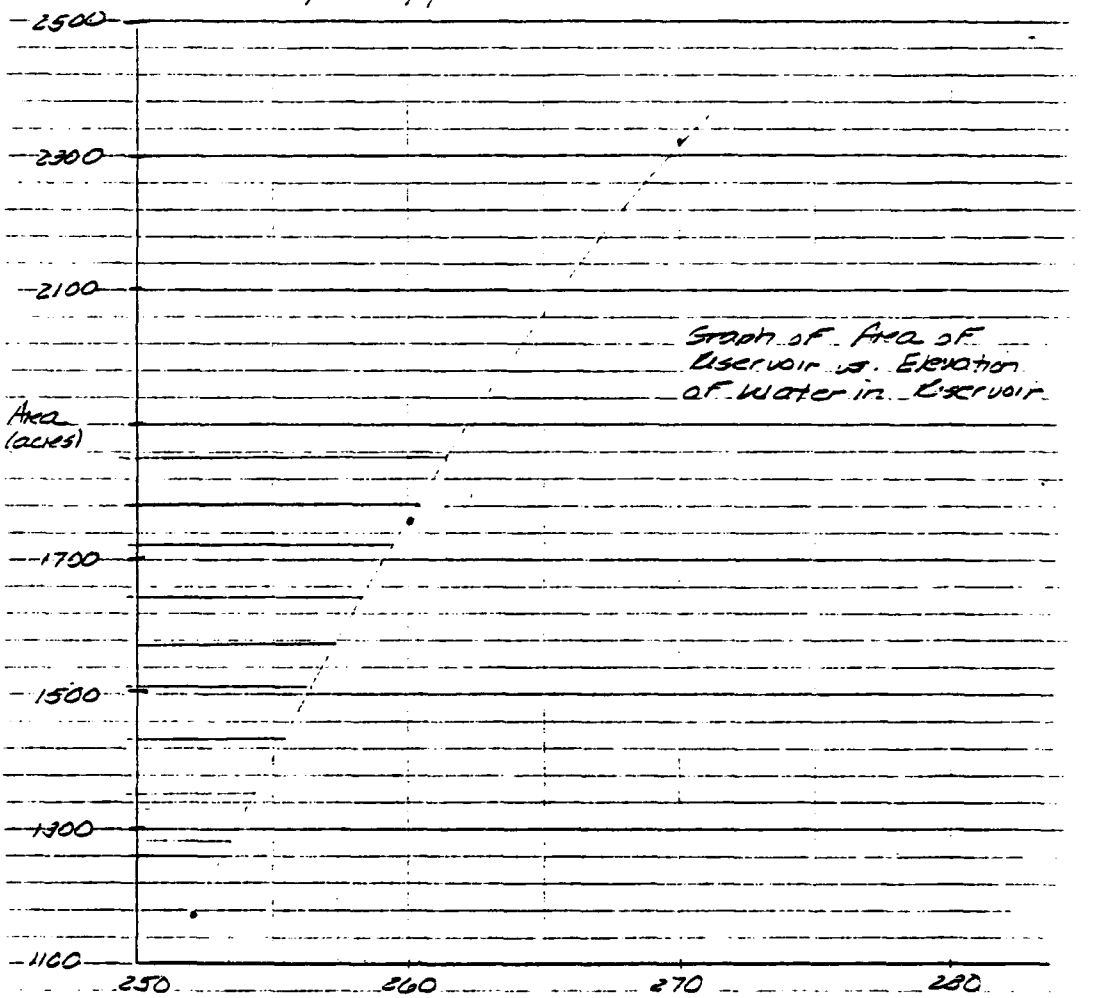
Boston, Mass.

CLIENT MBTA, U.D.T. Group 2 JOB NO. 561-B-RT PAGE 10
PROJECT Sudbury, Dam DATE CHECKED 8-21-78 DATE 7/7/22
DETAIL Hydrology CHECKED BY [illegible] COMPUTED BY dlm



Elevation of Spillway Crest - 259 - 5.65 = 253.35 NGVD

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Environmental Engineers
Boston, Mass.

CLIENT [illegible] JOB NO. [illegible] PAGE 11
PROJECT [illegible] DATE CHECKED 8-21-78 DATE 7/17/78
DETAIL Hydrology CHECKED BY [illegible] COMPUTED BY [illegible]

Calculation of Functional Rates of Storage

Elevation of Water on Spillway	Hd. on Spillway (ft.)	Reservoir Area, A (acres)	Calculated Outflow Q (cfs)	Storage Above Spillway	$\frac{S}{\Delta t}$ (cfs)	$\frac{S}{\Delta t} - \frac{Q}{2}$ (cfs)	$\frac{S}{\Delta t} + \frac{Q}{2}$
253.35	0	1280	0	0	0		
254.35	1	1350	980	1315	63646	63156	64136
255.35	2	1435	2970	2708	131,067	129582	132552
256.35	3	1510	5750	4180	202312	199437	205187
257.35	4	1570	9220	5720	276848	272238	281458
258.35	5	1645	13380	7328	354675	347985	361365
259.35	6	1720	18080	9010	436084	427044	445124
260.35	7	1780	23220	10760	520784	509174	532394
261.35	8	1850	28920	12575	608630	594170	623090

$\Delta t = 15$ min $= 900$ sec

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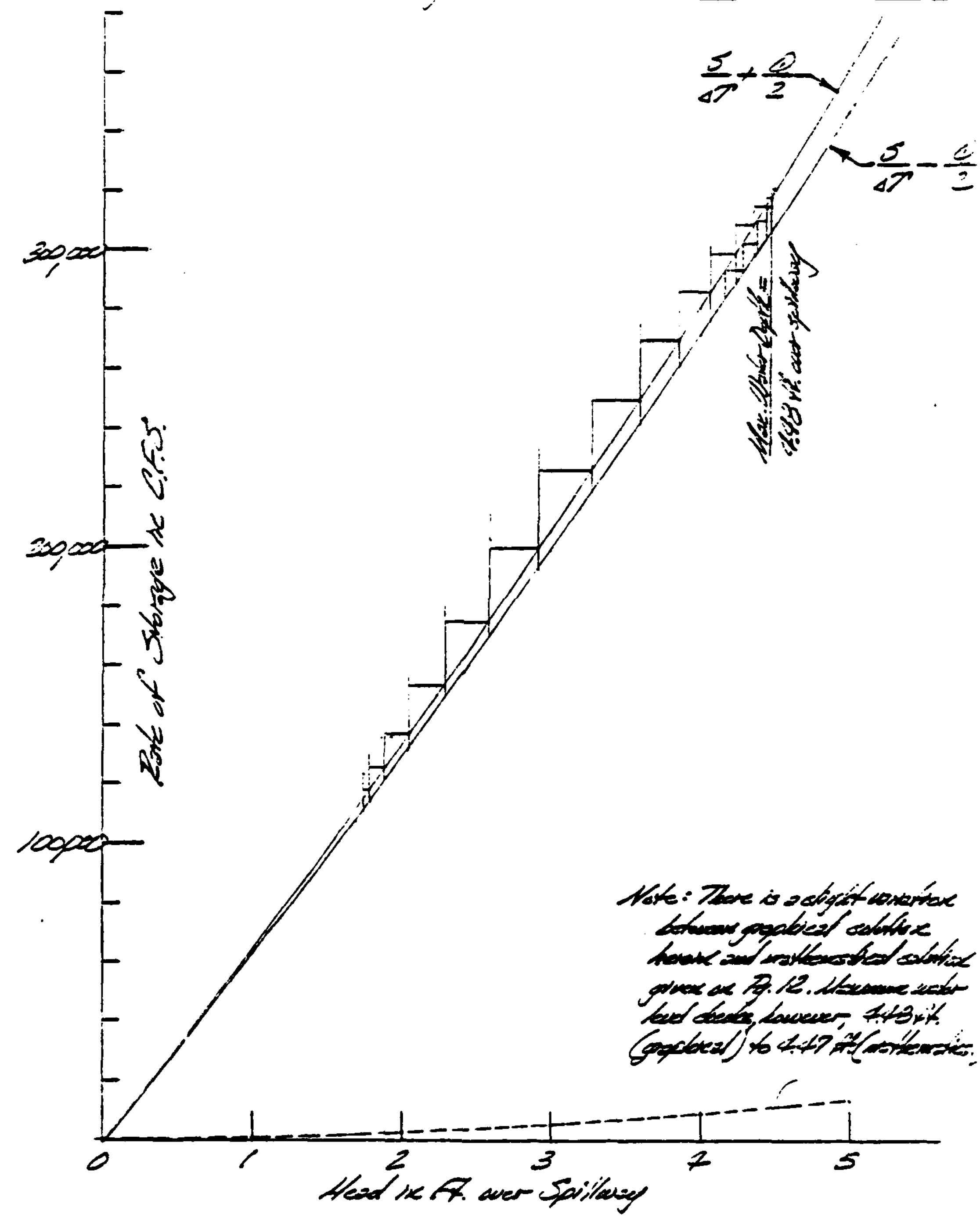
Boston, Mass.

CLIENT Woburn Charles River Impact JOB NO. 261-9-07 PAGE 12 of
PROJECT Sup I - Future Conditions DATE CHECKED 7/26/78 DATE
DETAIL Flood Routing CHECKED BY Abd COMPUTED BY

CALCULATION OF RESERVOIR OUTFLOWS

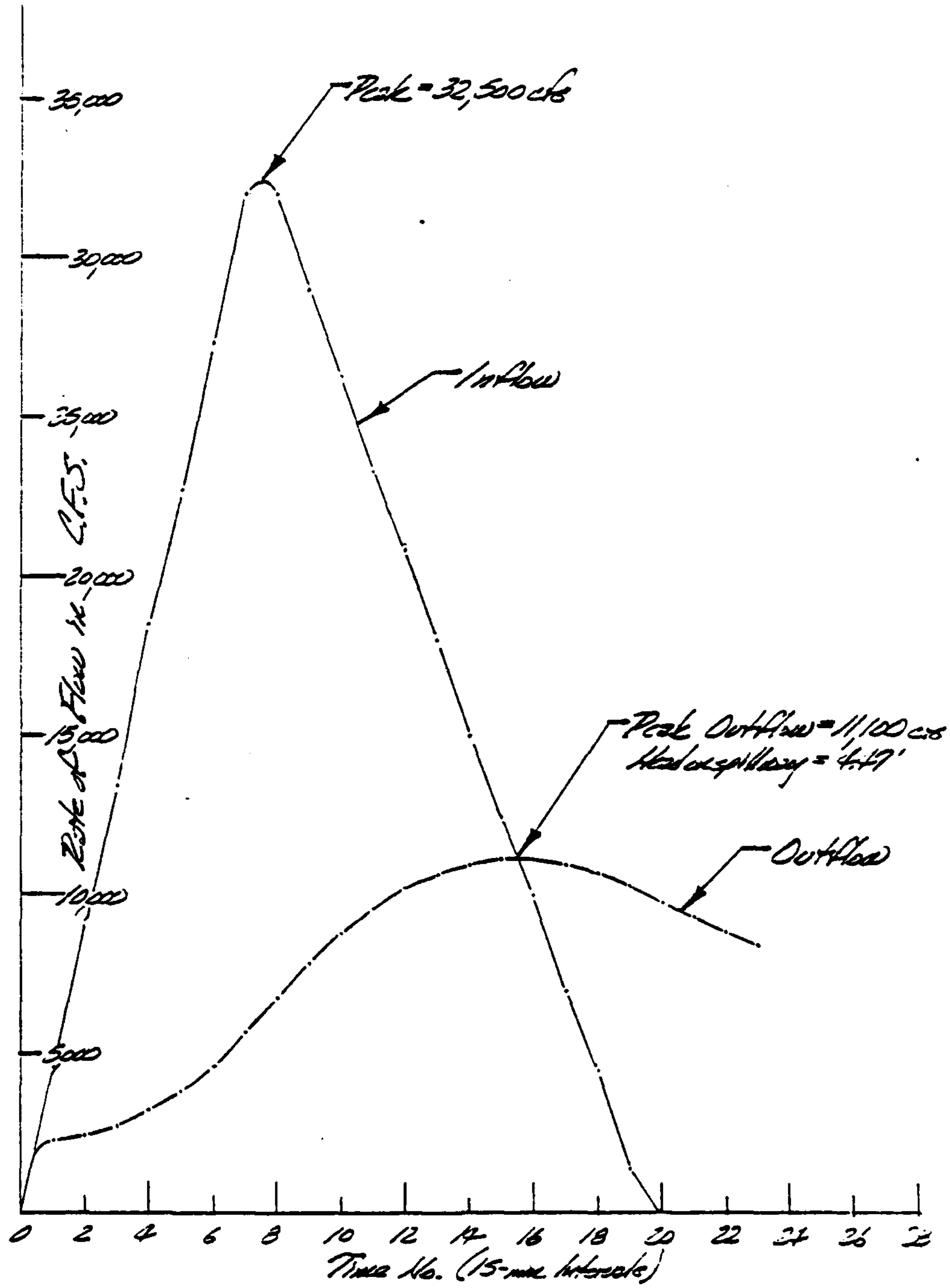
Time No.	Observed Inflow (cfs)	Average Inflow (cfs)	$\frac{S}{\Delta t} - \frac{O}{2}$	$\frac{S}{\Delta t} + \frac{O}{2}$	Head on Spillway (ft)	Outflow O (cfs)
0	0	0				
1	4,600	2300			1.75	2,380
2	9,200	6900	111,000	119,900	1.73	2,460
3	13,400	11,300	115,356	126,656	1.91	2,760
4	18,500	15,950	123,853	139,803	2.10	3,210
5	22,700	20,600	136,560	157,160	2.34	3,320
6	27,300	25,000	153,348	178,348	2.63	4,610
7	32,000	29,650	173,529	203,179	2.97	5,670
8	32,000	32,000	197,506	229,506	3.32	6790
9	29,000	30,500	222,650	253,150	3.63	7,340
10	26,300	27,650	245,218	273,868	3.89	8,790
11	23,300	24,800	264,038	288,838	4.09	9,580
12	20,900	22,100	279,234	301,334	4.25	10,200
13	19,000	19,950	291,079	310,529	4.36	10,620
14	15,000	16,500	299,796	316,296	4.44	10,950
15	12,400	13,700	305,262	318,962	4.47	11,110
16	10,000	11,200	307,790	318,990	4.47	11,110
17	7,000	8,500	307,816	316,816	4.44	10,950
18	4,500	5750	305,281	311,031	4.37	10,690
19	1,400	2,950	300,272	303,222	4.27	10,270
20	0	700	292,868	293,568	4.15	9,790
21	0	0	283,718	283,718	4.03	9,320
22	0	0	274,320	274,320	3.91	8,930
23	0	0	265,482	265,482	3.79	8,430



$\frac{S}{\Delta T} + \frac{Q}{2}$
$\frac{S}{\Delta T} - \frac{Q}{2}$
300,000
200,000
100,000
Rate of Storage in C.F.S.
Max. Water Depth = 4.43 ft. over Spillway
Note: There is a slight variation between graphical solution herein and mathematical solution given on Pg. 12. Maximum water level checks, however, 4.43 ft. (graphical) to 4.47 ft. (mathematical).
0
1
2
3
4
5
Head in Ft. over Spillway

CAMP DRESSER & McKEE
ENVIRONMENTAL ENGINEERS
BOSTON, MASS.

CLIENT [illegible] JOB NO. 561-8-RT PAGE 14 of
PROJECT [illegible] DATE CHECKED 9/26/78 DATE [illegible]
DETAIL Flood Routing CHECKED BY [illegible] COMPUTED BY [illegible]



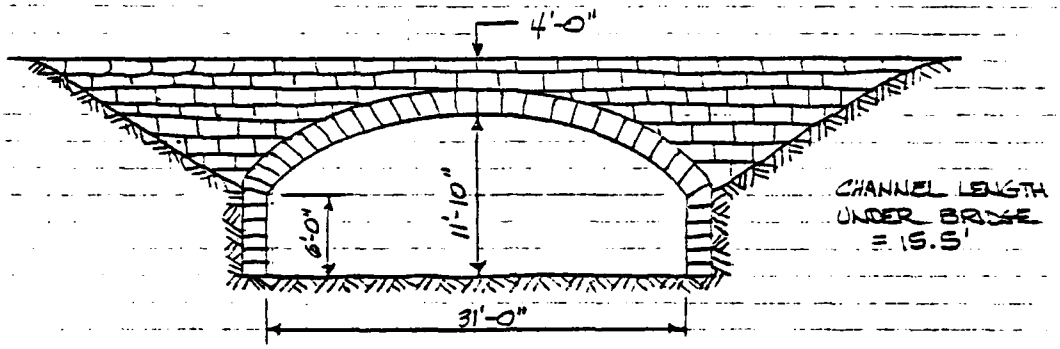
CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

CLIENT "ARMY" ALDRICH
PROJECT SUDBURY DAM
DETAIL

JOB NO 20-3-01
DATE CHECKED 3-21-78
CHECKED BY

PAGE 15
DATE 7-10-78
COMPUTED BY ED

TAILWATER ANALYSIS



CHANNEL LENGTH UNDER BRIDGE = 15.5'

PROBABLE MAXIMUM FLOOD = 8,100 cfs

AREA BELOW ARCH = 6' × 31' = 186 ft.²
AREA OF ARCH: (assume half ellipse)
A = ½π (15.5)(5.83) = 142 ft.²
} 328 ft² TOTAL

If Q is to pass thru bridge opening only,
then vel = 11,100 cfs / 328 ft.² ≈ 33.8 fps - too high
∴ PMF will overflow bridge

Not possible to determine depth of flow without knowing downstream topography

CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

CLIENT HALEY & ALDRICH
PROJECT NAT'L DAM INSP.
DETAIL SUDBURY DAM

JOB NO. 561-9-RT
DATE CHECKED 8-21-79
CHECKED BY [illegible]

PAGE 12
DATE 8-31-79
COMPUTED BY [illegible]

DAM FAILURE ANALYSIS

1. STORAGE WITH W.S. AT TOP OF DAM (EL. 220.35) = 32,857 ac-ft.

2. $Q_{P_1} = 8/27\ W_b\ (g)^{1/2}\ Y_o^{3/2}$

$Y_o = 30$ ft. let $W_b = 975' \times .4 = 390'$

L = Rt. Dam = 975'
Lt. Dam = 725' } TOTAL ≈ 2000'
Spillway = 300'

$Q_{P_1} = 8/27 \times 390 \times (32.2)^{1/2} (30)^{3/2} = 231,332$ say 230,000 cfs

3. Let Reach No. 1 be from Sudbury Dam to Mass. Turnpike

W.S. El. @ Mass. Turnpike ≈ 204 USGS (from next page of calc.)

Further analysis not req'd since

1) Severe damage & loss of life will result in reach No. 1 (See USGS Quad)

2) Data not available for downstream controls

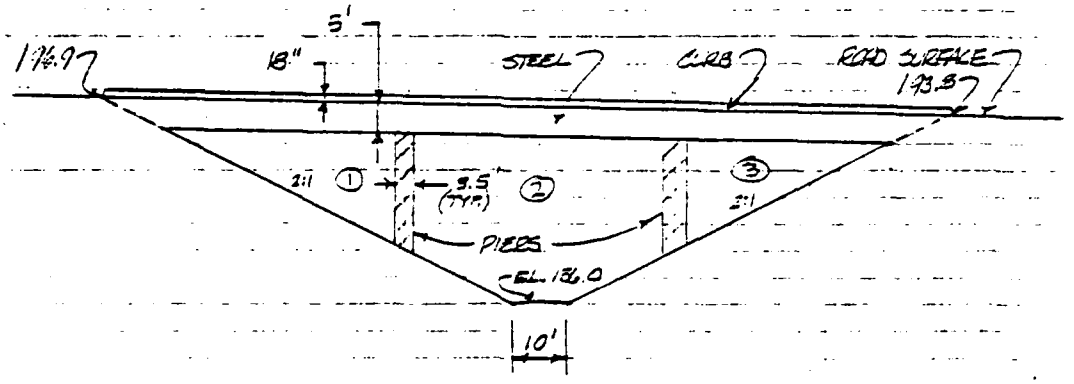
CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

CLIENT HALEY & WARD
PROJECT LT. DAM END
DETAIL 4:00 PM BY SAM

JOB NO. 201-R-RT
DATE CHECKED 8-21-79
CHECKED BY [illegible]

PAGE 17
DATE 8-14-79
COMPUTED BY SD

RT. 90 - MASS. TURNPIKE OVER RESERVOIR NO. 3



TOTAL AREA OF OPENG:

$10' \times 32. + (63 \times 32 \times 1/2) \times 2 - 3.5 \times 22 \times 2 = 2182$ s.f.

W.S. @ EL. 197.0: Weir Length = 1450'

$Q = (2.5)(1450)(1.7)^{3/2} + (0.8)(2182)(2 \times g \times 9)^{1/2} = 6,040 + 42,030$

$= 50,070$ cfs

W.S. @ EL. 198.5: Weir Length = 1550'

$Q = (2.5)(1550)(3.2)^{3/2} + (0.8)(2182)(2 \times g \times 10.5)^{1/2} = 22,180 + 45,390$

$= 67,570$ cfs

W.S. EL. 200.0: Weir Length = 1600'

$Q = (2.5)(1600)(4.7)^{3/2} + (0.8)(2182)(2 \times g \times 12)^{1/2} = 42,700 + 46,590$

$= 89,290$ cfs

W.S. EL. 205.0 Weir Length = 2650'

$Q = (2.5)(2650)(9.7)^{3/2} + (0.8)(2182)(2 \times g \times 17)^{1/2} = 220,150 + 57,760$

$= 277,910$ cfs

$\therefore \Sigma Q_{P1} = 232,000$ cfs

W.S. El. $= (232,000 - 89,300) / (277,910 - 89,300) \times 5.0 + 200.0$

$= 0.65 \times 5 + 200 = 204.2$

APPENDIX E
INFORMATION CONTAINED IN THE NATIONAL INVENTORY OF DAMS

INVENTORY OF DAMS IN THE UNITED STATES

(1) STATE	(2) IDENTITY NUMBER	(3) DIVISION	(4) STATE	(5) COUNTY	(6) CONGR DIST.	(7) STATE	(8) COUNTY	(9) CONGR DIST.	(9) NAME	(15) LATITUDE (NORTH)	(16) LONGITUDE (WEST)	(17) REPORT DATE DAY | MO | YR
MA	741	NED	MA	027	02				SUDBURY DAM	4218.4	7129.6	08SEP78

(18) POPULAR NAME	(19) NAME OF IMPOUNDMENT
	SUDBURY RESERVOIR

(18) REGION	(19) BASIN	(11) RIVER OR STREAM	(12) NEAREST DOWNSTREAM CITY–TOWN–VILLAGE	(13) DIST FROM DAM (MI.)	(14) POPULATION
01	05	STONY BROOK	SOUTHBOROUGH	0	6326

(20) TYPE OF DAM	(21) YEAR COMPLETED	(22) PURPOSES	(23) STRUCTURAL HEIGHT (FT.)	(24) HYDRAULIC HEIGHT (FT.)	(25) IMPOUNDING CAPACITIES MAXIMUM (ACRE–FT.)	(25) IMPOUNDING CAPACITIES NORMAL (ACRE–FT.)
RECTGRPG	1896	S	84	70	33020	22260

DIST	OWN	FED R	PRV/FED	SCS A	VER/DATE
NED	N	N	N	N	28AUG78

(26) REMARKS

(27) D/S HAS	(28) SPILLWAY CREST LENGTH	(29) SPILLWAY TYPE	(30) SPILLWAY WIDTH (FT.)	(31) MAXIMUM DISCHARGE (FT.)	(32) VOLUME OF DAM (CY)	(33) POWER CAPACITY INSTALLED (MW)	(34) POWER CAPACITY PROPOSED (MW)	(35) NAVIGATION LOCKS NO.	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)
1	2000	C	300	23200												

(41) OWNER	(42) ENGINEERING BY	(43) CONSTRUCTION BY
METROPOLITAN DIST. COMM	METROPOLITAN DIST. COMM	

(44) REGULATORY AGENCY DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE
NONE	NONE	NONE	

(45) INSPECTION BY	(46) INSPECTION DATE DAY | MO | YR	(47) AUTHORITY FOR INSPECTION
HALEY & ALDRICH, INC.	30JUN78	PUBLIC LAW 92-367

(48) REMARKS

END

FILMED

8-85

DTIC